



Forensic Science and Human Rights

National Human Rights Commission
India
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**National Human Rights Commission
India**



National Human Rights Commission

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Justice Arun Mishra
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Foreword

In the realm of criminal justice, forensic science plays a pivotal role in upholding the fundamental principles of fairness and impartiality. It provides an objective and scientific basis for investigating crimes, identifying perpetrators, and ensuring that justice is served. The National Human Rights Commission, NHRC, India recognizes the crucial importance of forensic science in safeguarding human rights and upholding the rule of law.

Forensic science, with its meticulous analysis and application, plays a vital and crucial role in safeguarding human rights by providing an objective lens through which the legal system can unravel the complexities of crime.

It is with great pleasure and a sense of profound responsibility that I extend my heartfelt commendation for this remarkable publication on forensic science. In a world where justice and human rights stand as the pillars of a civilized society, the role of forensic science cannot be overstated.

As we delve into the captivating realm of forensic science within the pages of this book, it is imperative to dedicate a moment to the increasingly crucial field of Digital Forensics. The digital age is beneficial to advancement and development. In a world where technology shapes our daily lives, understanding the intricacies of digital forensics is not just a professional necessity but a societal imperative. However, the Dark Web accounts for 96% of all cyberspaces, which is a menace to civilization. It is being used for illicit objectives such as child exploitation, eroding the right to privacy, contemporary slavery, trafficking, and extortion via data hacking.


This comprehensive book on forensic science is a timely and valuable contribution to the field. It provides a comprehensive overview of the various branches of

forensic science, including their principles, techniques, and applications. The book also delves into the ethical and legal considerations surrounding forensic science, ensuring that practitioners adhere to the highest standards of professionalism and integrity. This book not only elucidates the technical aspects of forensic investigation but also underscores its profound implications for upholding the rights and dignity of individuals.

I express my deepest gratitude to Dr. J.M. Vyas, Vice Chancellor, National Forensic Sciences University for unhesitatingly accepting my request and for exceptional contribution to the book. I am truly appreciative of your tireless efforts for coordinating with the authors and bringing a final shape to the book. The dedication, expertise, and creativity have truly elevated the quality of the book, making it a valuable and enriching resource for readers. I also thank all the authors and co-authors for their contributions.

The NHRC is committed to promoting the effective utilization of forensic science in the criminal justice system. This book serves as an invaluable resource for law enforcement officials, forensic scientists, legal professionals, and human rights advocates. It will undoubtedly contribute to enhancing the quality and effectiveness of forensic investigations, leading to a more just and equitable society.

This book is an essential addition to the forensic science literature and will undoubtedly serve as a valuable resource for years to come. May this book serve as a beacon, guiding us toward a future where the principles of justice and human rights are unwaveringly upheld.


(Justice Arun Mishra)

भरत लाल
महासचिव
Bharat Lal
Secretary General



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December 10, 2023



Preface

Forensic Science has emerged as a crucial instrument within the dynamic realm of crime and justice, shedding light on the intricate processes essential for uncovering truth and administering justice. The significance of forensic science transcends conventional boundaries, immersing readers in the complex landscape of investigations into human rights violations. A nuanced understanding of forensic science has become imperative for safeguarding the human rights and ensuring liberty, and dignity of individuals.

This publication is a comprehensive journey into the dynamic methodologies, cutting-edge technologies, and the moral and ethical considerations underpinning contemporary forensic investigations. As the challenges of crime surpass human capabilities, this book assumes the role of a guide, empowering readers to align with the bold stance required in the pursuit of justice.

This book confronts the need for a seamless integration of theory and practice. It emphasizes the importance of equipping professionals with multi-domain knowledge. Rather than circumventing limitations, this narrative confronts them head-on. By fostering knowledge that advocates truth and justice, the book advances the stance of legal and human rights institutions by dispelling shadows of doubt and malfeasance over evidentiary accounts.

In navigating the unexplored territories of forensic science, various articles in the book boldly extend the boundaries of foundational limitations. It highlights excellence within the accessible resources, delineating principles, techniques, innovations, and diverse applications for professionals engaged in the pursuit of truth. The chapters delve into multi-lateral applications aligned with emerging trends and challenges in human rights violations, providing practitioners with a comprehensive understanding that exceeds traditional disciplinary confines.

The book also addresses the pressing need to comprehend the core principles of human rights investigations. By showcasing the potential of forensic science to contribute to the prevention and redress of human rights violations, the book emerges as a reliable resource for a diverse spectrum of professionals.

In the ensuing chapters, the reader embarks on a journey that extends beyond the conventional boundaries of forensic science, exploring its significance, emerging trends, and the imperative need for a deeper understanding in the pursuit of truth and justice. This book is not merely a documentation of forensic science's current state; it is a roadmap guiding us toward its leading role in shaping a just and equitable society.



(Bharat Lal)

देवेन्द्र कुमार निम
संयुक्त सचिव
Devendra Kumar Nim
Joint Secretary



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Acknowledgement

Forensic science, a multidisciplinary field encompassing various scientific disciplines, has long played a pivotal role in the criminal justice system, aiding in the investigation of crimes. The nexus between scientific methodologies and the protection of human rights underscores the delicate balance between justice, truth, and ethical considerations, which ensures promotion and protection of human rights.

This comprehensive work on forensic science stands as a testament to the dedication and expertise of those involved in its production. The meticulous exploration of forensic methodologies within these pages not only deepens our understanding of the subject but also emphasizes its critical role in ensuring justice and upholding human rights.

I am deeply honored to extend my sincere appreciation and acknowledgment for the creation of this invaluable book on forensic science. As the Joint Secretary of the National Human Rights Commission, I find great significance in the intersection of forensic science and the protection of human rights. This book undoubtedly will serve as a vital resource for professionals in the legal and law enforcement sectors, contributing to the enhancement of our collective knowledge and practices.

The foremost person I would like to thank and place on record my sincere gratitude to is Mr. Justice Arun Mishra, Hon'ble Chairperson, National Human Rights Commission, for his persistent guidance and support. It would not have

been possible to publish this book without his wholehearted involvement and motivation.

I also express my gratitude to Dr. Dnyaneshwar Manohar Mulay and Mr. Rajiv Jain, Hon'ble Members, NHRC, for their inputs and support. In addition I place on record my gratitude to Mr. Bharat Lal, Secretary General, NHRC, for his unwavering support and guidance, which made it possible to release this book on Human Rights Day.

I extend my gratitude to the authors for their meticulous research and commitment to shedding light on the intricate relationship between forensic science and the preservation of human dignity. I would like to sincerely thank Dr. J.M Vyas, Vice Chancellor, National Forensic Science University for his cooperation and contribution in the book. I express my deepest gratitude to the authors and co-authors, Shri Rajiv Jain, Dr. Astha Pandey, Dr. Bhoomika Patel, Dr. S.K. Jain, Shri Keshav Kumar (IPS retd.), Dr. Madhulika Sharma, Dr. Adarsh Kumar, Dr. Satish Kumar, Dr. G. Rajesh Babu, Dr. Abraham Johnson, Dr. Digvijaysinh Rathod, Dr. Surbhi Mathur, Dr. Nilay Mistry, Shri Sarang Rajvansh, Dr. Naveen Kumar Chaudhary, Dr. Priyanka Kacker, Dr. Pooja Ahuja, Dr. Saurabh Kumar, Shri Malay A. Shukla, Shri Bhargav C. Patel, Dr. S. O. Junare, Dr. Haresh Barot and Prof. Dr. Purvi Pokhariyal and Ms. Deepa Dubey.

I would also like to acknowledge and compliment Shri Surajit Dey, Registrar (Law) and Shri Sunil Kumar Meena, DIG (Investigation) for their support in compilation of the chapters. I would also like to appreciate contribution of the in-house team of NHRC consisting of Lt. Col. Virender Singh, Director, Shri Utpal Sarkar, A D (P) and Shri Sajith Mohamad Saleem, Junior Research Consultant for their support and assistance.

In conclusion, my heartfelt appreciation goes out to everyone involved in the creation of this insightful and informative work. May it serve as a guiding beacon for those committed to the pursuit of justice and the protection of human rights.


[Devendra Kumar Nim]

Chapter 1

Introduction

Rajiv Jain¹

The phenomenon of crime is as old as human civilization. Consequently, laws evolved and, thereby, did the societal norms. Irrespective of Age, crime has always been a part of human lives. Humans had to relinquish some of their liberties to be a part of society. People who did not follow the set norms were identified, segregated from the mainstream of society and punished so that the process acts as a deterrent. This eventually led to the establishment of investigation, prosecution and judicial institutions. However, the criminal justice delivery system initially depended on eyewitnesses who 'swore' in God's name. This institution of 'witnesses' did not prove effective as they were found to turn hostile often due to threat of life or lure of money and hence lacked consistency. The police subculture also leads to torturous methods in the investigation, directly impacting the violation of their rights.

Significant advancements have taken place in various branches of science. It was visualized that modern scientific techniques can provide quick and rational solutions to most problems. When the application of science in solving crime cases increased, its real strength in providing clinching evidence was slowly realized worldwide. India did not lag far behind, and a few 'Laboratories of Chemical Examiners' was established during the middle of the nineteenth century. Still, their role was limited, and hardly any expansion took place for nearly another hundred years.

The successful investigation of crime and fair administration of justice depends on the quality of evidence. If the quality of the evidence is poor, as has been the case with eyewitness testimony, the criminals manage to go unpunished. Therefore, the urgency was felt to expand forensic science facilities to improve the quality of evidence. With this aim, the Government of India prepared a model scheme in 1958 and decided to introduce the concept of forensic science in the Indian criminal justice system by setting up Forensic Science Laboratories. Further, to strengthen these laboratories, the Government of India introduced a scheme to modernize State police forces. However, for the last few

¹ Member, National Human Rights Commission, India



decades, with whatever funds were given to the Forensic Science Laboratories, both from the Central and the State resources, the developments that took place have not been adequate to cope with the increasing workload of crime case examination in the laboratories. Regional Forensic Science Laboratories and District Mobile Forensic Science Laboratories have also been established in some states. However, for want of a factorable environment, where forensic science should be a 'societal mission', the scientists should be groomed to work with zeal and dedication. Although some developments have been observed, much needs to be done. The Forensic Science set up in the country needs "reforms and restructuring" so that it cannot only cope with the heavy workload of crime cases but also handle the changing trends in crime and offer clinching evidence strong enough to identify and lead to convictions.

The advancements in science and technology, socio-economic upheavals, population growth, easy access to scientific knowledge, better communication and transport facilities, and contemporary and organized crimes pose new challenges; a fresh look at Forensic Science Laboratories has become necessary. In India, where most of the population is illiterate and uneducated, the social setup is heterogeneous, lack of police-public relationships, rampant poverty and unemployment directly affects the case, and witnesses in many cases can turn hostile, implying the urgent need to induce rational and scientific methods to fight crime. Only Forensic Science can offer objective and reliable evidence. Modern automation in analysis methods has given a new pace to examining various crime clues. The speedy evidentiary Forensic reports will also have an immense social impact.

Many new scientific techniques have become available due to the tremendous advancements in science and technology, which the India Forensic Science Laboratories are slowly adapting. Employing scientific methods can solve the majority of cases. But there are many court judgments in which strictures are passed against the investigating agencies for inadequate investigation or inability to collect sufficient evidence. Because of such judgments, the Forensic Science Laboratories' workload has rapidly increased. This has resulted in accumulated pendency in most State Forensic Science Laboratories, which are staff-starved; resource crunched and lacked the desired infrastructure facilities. The concerned laboratories pointed out these inadequacies repeatedly, but unfortunately, no one took any initiative to reshape the setup. Looking into the causes of justice delayed due to the delay in the availability of forensic evidence, the NHRC took the initiative to look into what hails the Forensic Science Laboratories in the country and identify the ways and means to make them efficient for meeting the demands placed on them.

Chapter 2

The Imperative of Forensic Justice in Modern Legal Systems: A Comprehensive Analysis

Purvi Pokhariyal¹ and Deepa Dubey²

Abstract

Forensic justice, an indispensable pillar of contemporary jurisprudence, beckons the clarion call for meticulous policy delineations to realize its multifarious potential. Through this chapter, we embark upon a systematic study into the precincts of forensic justice, meticulously revealing its nuanced intricacies and profound ramifications.

Our incipient narrative underscores the pivotal role assumed by forensic justice in the annals of modern legal enforcement. It explores, the inexorable need for sagacious policy stratagems that can harness its kaleidoscopic capabilities. Subsequently, the exposition unveils the extant of forensic justice, explaining how it aids criminal investigations and the challenges law enforcement faces. The chapter traces the technological progress, shedding the spotlight on recent and impending innovations within the precincts of forensic science. Further, the Chapter underscores the strident need for infrastructural fortification, training, and public awareness programs to strengthen forensic capabilities.

Finally, the chapter culminates with a comprehensive conclusion that encapsulates the key policy recommendations outlined throughout the research. It reinforces the significance of well-informed policies in fully realizing the potential of forensic justice, ultimately contributing to a more equitable and effective criminal justice system.

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1. Introduction

In the intricate fabric of a just and democratic society, justice stands as the quintessence, a beacon guiding human interactions and shaping the allocation of resources and opportunities. Its lofty ideals of fairness, impartiality, and equity resonate deep within the human experience, casting a profound shadow that touches every facet of our existence. Justice, in its purest form, demands that each individual be accorded their rightful due, shielded from the capricious winds of prejudice or favoritism. At its core, justice calls upon us to cast aside the heavy shackles of discrimination, ensuring that no one is marginalized or denied their inherent right to a fair trial, a right that extends even to the accused. (Cusack et al., 2010)

Truth is central to justice, and evidence is the means by which we aim to uncover it. In the realm of a courtroom, truth is primarily sought through witness testimony, where people recount their versions of events. However, in the complex tapestry of real life, witness statements can be influenced by various factors such as manipulation, coercion, personal vendettas, fading memories, and animosities. When these vulnerabilities are exploited, it can result in a miscarriage of justice.

To address this significant challenge, forensic evidence emerges as a beacon of hope, ensuring fairness in investigations, which are the foundation of a fair trial. Forensic experts provide impartial, compelling, and scientific evidence that supports the sequence of events, with the ultimate goal of ensuring flawless justice. This blending of science and justice gives rise to the concept of forensic justice, a dynamic and evolving field that aims to harmonize scientific methods, legal principles, and ethical considerations.

Forensic justice requires consistent adherence to laws and methods that promote greater accountability within the criminal justice system. It compels us to confront historical injustices, break down entrenched biases, and foster inclusivity in society. It calls for a thorough examination of past wrongs, utilizing forensic analysis tools to shed light on unresolved cases or reevaluate convictions. This process leads to a new perspective on forensic justice, one that prioritizes rectifying injustices and promoting empathy, compassion, and equality.

The advent of science and technology has dramatically transformed the landscape of crime, criminals, and criminal investigations. In this era of rapid technological progress, forensic science has become the cornerstone of criminal



inquiry. Techniques like DNA analysis, fingerprinting, ballistics, and toxicology have greatly enhanced the accuracy and reliability of evidence analysis. These advances not only expedite criminal investigations but also have the potential to exonerate individuals who have been wrongfully convicted. (Walsh et al., 2004)

Moreover, the emergence of digital forensics in the age of digitalization has paved the way for effective and reliable investigations in the digital realm. These technological advancements are revolutionizing the field of forensic science, enhancing the accuracy, efficiency, and scope of forensic investigations. Yet, with these advancements come ethical considerations and challenges.

Protecting privacy rights, ensuring data integrity, managing biases in algorithms and forensic techniques, and addressing the digital divide are crucial aspects that require careful attention. Ethical guidelines and regulations are necessary to maintain transparency, accountability, and fairness in the use of science and technology in the pursuit of justice. (Bartusiak, 2011)The paradigm shift in the criminal justice system driven by science and technology has transformed the investigation, analysis, and delivery of justice. Advancements in forensic science, the integration of technology, the rise of digital forensics, and the implementation of automation have revolutionized the field. However, striking a balance between technological advancements and safeguarding fundamental principles of justice is imperative. To navigate this evolving landscape of forensic justice effectively, a structured approach is necessary. This chapter embarks on a comprehensive exploration of forensic justice within a structured framework, addressing key dimensions that shape its significance and impact.

The subsequent sections will provide a concise overview of the current state of forensic justice, including its role in criminal investigations and the challenges faced by law enforcement agencies. The chapter will also delve into recent and upcoming technological advancements in forensic science, discussing how these innovations can enhance the accuracy, efficiency, and scope of forensic investigations. Policy recommendations will be meticulously outlined, covering diverse aspects such as data management and sharing, quality control, research and development funding, and interdisciplinary collaboration. Ethical and legal considerations in forensic justice will be explored, with a focus on privacy protections and the regulation of emerging technologies. Capacity building and



training will emerge as critical components of forensic justice, emphasizing the need for infrastructural development, workforce training, and public awareness programs to strengthen forensic capabilities. The chapter will also discuss the importance of international cooperation in forensic justice, examining global standards and the potential for joint investigative efforts.

To concretize forensic justice in India, understanding its underpin tenets infused within criminal investigation is absolutely imperative. Through informed policy decisions and a deep appreciation of the interplay between science and justice, we can navigate the path to forensic justice effectively, contributing to a more equitable and effective criminal justice system.

2. The Current State of Forensic Justice

Human accounts are often influenced by factors like manipulation, pressure, faulty memory, and personal biases, which can lead to unjust outcomes in legal cases. Witness statements, which form a crucial part of legal proceedings, can be influenced by personal grudges and prejudices, resulting in miscarriages of justice. On the flip side, forensic evidence offers an impartial and solid foundation for investigations, relying on concrete evidence to establish the facts. However, the current state of forensic justice falls short in many respects. In numerous regions, the effective use of forensic expertise is hindered by limited resources and a lack of awareness within the criminal justice system, leading to prolonged cases and delayed justice. The existing condition of forensic justice in India exhibits notable advancements alongside ongoing challenges. Although forensic science has made significant strides in recent times, there are still pressing issues that require attention and resolution.

India has witnessed notable developments in the recognition and utilization of forensic evidence within its criminal justice framework. These advancements are reflective of a growing commitment to enhancing the role of forensic evidence in the investigative and adjudicative processes.

The Indian government has undertaken legislative measures aimed at fortifying the position of forensic evidence in criminal proceedings. Notably, the enactment of the Bharatiya Nagarik Suraksha Sanhita, 2023 (Bill No. 122) and the Bharatiya Sakshya Bill, 2023 (Bill No. 123) underscores a dedication to improving forensic practices. These legislative initiatives underscore the imperative of involving forensic experts as a mandatory component of crime scene investigations, especially in cases carrying severe punitive ramifications.

Recognizing the exigency of addressing case backlogs awaiting forensic analysis, the government has directed additional resources toward forensic laboratories. This financial infusion is intended to augment the infrastructure and operational capacity of forensic facilities, ultimately expediting the collection and examination of evidentiary materials.

3. Pioneering Technological Advancements

Recent advancements in the field of forensic science mark a transformative epoch distinguished by precision, efficiency, and the expansive scope of capabilities. Emerging technologies, such as DNA fingerprinting, voice spectroscopy, and deception detection techniques (DDTs) including narco-analysis, polygraph examinations, and brain mapping, have engendered a paradigm shift within this domain. These innovations are fundamentally reshaping the landscape, holding profound implications for the identification of wrongdoers and the exoneration of the unjustly accused making it imperative to undertake a comprehensive examination of few developments:

3.1 DNA Profiling: DNA fingerprinting, more formally referred to as DNA profiling, stands as an indomitable pillar in contemporary forensic science (Ugarković & Plohl, 2002). It encompasses the meticulous scrutiny of an individual's distinct DNA pattern, with a primary reliance on short tandem repeat (STR) analysis. Recent advancements in DNA analytical techniques have conferred the capacity to work with minute or degraded samples, thereby substantially broadening its applicability within criminal investigations. Furthermore, the amalgamation of DNA databases has significantly augmented the capacity to align DNA profiles with known individuals and unresolved cases.

3.2 Voice Spectroscopy: Voice spectroscopy, as a leading-edge technological pursuit, is centered upon the scrutiny of the acoustic attributes inherent in an individual's vocal expressions (Gruber et al., 2020). This technology holds the potential to facilitate speaker identification and discern emotional states predicated upon vocal cues. Recent strides in voice spectroscopy algorithms and machine learning algorithms have notably enhanced the precision and dependability of voice analysis, thereby rendering it an invaluable instrument in the realm of forensic voice comparison.

3.3 Deception Detection Techniques (DDTs)

3.3.1 Narco-Analysis: Narco-analysis is a procedure involving the administration of a truth serum or psychoactive substance to a subject, thereby inducing a

state of semi-consciousness (Podlesny & Raskin, 1978). This altered state may render individuals more disposed to divulging information they might otherwise withhold. Recent progress in pharmacology and neuroscience has led to the refinement of narco-analysis techniques, resulting in heightened efficacy and reliability in the extraction of information.

3.3.2 Polygraph Examinations: Polygraph, commonly referred to as a lie detector, entails the measurement of physiological responses such as heart rate, blood pressure, and respiration to gauge the veracity of statements. Recent enhancements in polygraph technology, including the incorporation of computerized data analysis and improved sensor mechanisms, have substantially elevated the accuracy of polygraph examinations in contemporary times (Staunton & Hammond, 2011).

3.3.3 Brain Mapping: Brain mapping methodologies, including functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), have garnered significant attention for their utility in deception detection. These techniques involve the monitoring of neural activity to discern patterns associated with deception or truthfulness (Baillet et al., 2001). Ongoing research and technological refinements continually augment the precision of brain mapping for forensic applications.

These progressive developments collectively furnish forensic practitioners with potent instruments to scrutinize evidence and evaluate the credibility of witnesses and suspects. They contribute substantively to the refinement of investigative processes, culminating in the precise identification of wrongdoers and the safeguarding of the innocent. As forensic science perpetually evolves, it holds the promise of further amplifying the criminal justice system's capacity to unearth truth and dispense equitable outcomes.

4. Recommendations for Policymakers

4.1 Data Management and Sharing

The bedrock of a robust forensic justice system hinges upon the effective management and dissemination of data. In India, the multifaceted spectrum of forensic data amassed by diverse law enforcement entities at both the state and national tiers necessitates a methodical approach to data governance and sharing. The recent enactment of the Criminal Procedure (Identification) Act, 2022 has substantially expanded the ambit of permissible measurements for identification and investigatory purposes. However, this expansion concurrently accentuates

the exigency for a structured and efficient framework for the management and sharing of data.

Under the aegis of the 2022 Act, the purview of permissible measurements now encompasses a wide array, spanning from finger and palm print impressions to footprint impressions, photographs, iris and retina scans, physical and biological specimens, and behavioral attributes, including signatures and handwriting. While this broadened scope aligns harmoniously with the modernization of criminal investigation techniques, it simultaneously engenders formidable challenges in the realm of data stewardship and security.

To confront these challenges effectively, policymakers must accord paramount importance to the establishment of centralized data repositories, meticulously devised to comprehensively house and manage forensic data. (Klaasse et al., 2021) These repositories should serve as secure nuclei where data derived from manifold sources, including Central and State Forensic Science Laboratories, law enforcement agencies, and the National Crime Records Bureau (NCRB), can be seamlessly amalgamated. The centralization of these repositories confers a constellation of advantages:

- i.) **Augmented Accessibility:** Authorized law enforcement agencies operating throughout India should be furnished with streamlined access to these centralized repositories. Such accessibility would not only expedite investigatory processes but also engender a culture of information sharing, thereby nurturing a collaborative ethos conducive to the resolution of criminal cases.
- ii.) **Data Integration:** Centralized repositories enable the integration of diverse forensic data types, such as DNA profiles, fingerprint records, behavioral attributes, and more. This holistic view of forensic information equips investigators with a more comprehensive understanding of cases.
- iii.) **Efficiency:** By centralizing data management, redundant efforts and resource allocation can be minimized. Policymakers can implement standardized protocols for data entry, maintenance, and retrieval, optimizing the use of forensic data.
- iv.) **Data Security:** Establishing robust security measures within the repositories is paramount. Given the sensitive nature of forensic data, encryption, access controls, and data protection mechanisms must be implemented rigorously. Additionally, the 2022 Act should be complemented by data protection

legislation to safeguard individuals' privacy rights.

- v.) **Interoperability:** The centralized repositories should be designed with interoperability in mind, ensuring compatibility with existing and future forensic technologies. This adaptability will accommodate technological advancements while maintaining data integrity.
- vi.) **Long-Term Storage:** As per the 2022 Act, records of measurements must be preserved for 75 years. Establishing a centralized repository with the capacity for long-term storage is essential to meet this requirement.

However, while centralization offers significant benefits, it also raises challenges related to scalability, resource allocation, and data protection. The 2022 Act designates NCRB as the responsible entity for the collection and administration of records of measurements, but it's imperative to involve Central and State Forensic Science Laboratories in this process due to their expertise.

Moreover, as India lacks a comprehensive legal framework for data protection, policymakers must address this gap concurrently. Data protection legislation would be instrumental in safeguarding the privacy and rights of individuals whose measurements and biological samples are collected and stored. (Johnson, 2003)

The promulgation of the Criminal Procedure (Identification) Act, 2022 stands as a testament to India's resolve to contemporize its approach to criminal investigations. However, the effective execution of this legislative development rests upon the establishment of centralized repositories, exacting data governance protocols, and exhaustive safeguards for data protection. Policymakers are tasked with the intricate navigation of these hurdles, obligating them to exercise prescience in crafting a data management and sharing framework that seamlessly synchronizes with India's ever-evolving forensic knowledge landscape.

4.2 Quality Control and Standardization

In the relentless pursuit of a robust forensic justice system, the paramount objective lies in ensuring the utmost quality and standardization of forensic procedures. This imperative necessitates the meticulous implementation of stringent quality control measures and the formulation of standardized protocols, both of which serve as cornerstone elements in augmenting the credibility and reliability of forensic evidence proffered within the ambit of legal proceedings. Quality control within the realm of forensic science encompasses a multifaceted spectrum, encompassing diverse facets, of which the following are noteworthy:

- i.) **Laboratory Certification:** A seminal stride towards the realization of quality control objectives resides in the certification of forensic laboratories. These laboratories should diligently aspire to secure ISO certification, an internationally recognized benchmark for quality management. The attainment of ISO certification signifies a laboratory's unwavering commitment to the adherence of global best practices germane to the domain of forensic analysis.
- ii.) **Technological Advancements:** In the perpetual pursuit of elevated standards, forensic laboratories must equip themselves with contemporary technology and cutting-edge instrumentation. These technological strides not only amplify the precision and exactitude of forensic analyses but also confer upon laboratories the capability to manage their caseloads.
- iii.) **Workload Management:** A long pendency of cases can undermine the effectiveness of forensic evidence. Adequate equipment capacity and resources are essential to address this challenge effectively. Laboratories should be equipped to handle the incoming exhibits promptly, reducing delays in forensic analysis and case resolution.
- iv.) **Certified Forensic Experts:** The expertise of forensic professionals is a linchpin in ensuring quality. Forensic experts, whether employed by the government or in the private sector, should be registered and certified. Certification ensures that these experts meet predefined standards of competence and ethical conduct.
- v.) **Uniform Reporting Patterns:** Achieving standardization in forensic reporting is pivotal. Forensic reports should exhibit uniformity in format and content across the country. This consistency ensures that legal professionals, judges, and jurors can readily comprehend the findings, even without specialized scientific knowledge. Reports should be articulated in plain and understandable language, making complex scientific information accessible to non-scientific stakeholders.

The overarching objective of these quality control and standardization efforts is to instill confidence in the forensic evidence presented within the criminal justice system. This confidence extends to all stakeholders, including law enforcement agencies, legal practitioners, judges, and the general public.

By adhering to international quality standards, upgrading technology infrastructure, effectively managing caseloads, certifying forensic experts, and ensuring uniformity in reporting, India can bolster the credibility of its forensic evidence. Such measures not only enhance the efficiency of the criminal justice system but also contribute to the fair and equitable administration of justice.



Quality control and standardization stand as cornerstones upon which the integrity and reliability of forensic evidence rest, ultimately serving the cause of justice and truth.

4.3 Research and Development in pursuit of forensic justice

Investing in research and development (R&D) within the field of forensic science is not just an option; it's imperative to keep pace with the ever-evolving landscape of forensic technologies. In September 2020, the Ministry of Home Affairs (MHA), Government of India, took significant strides in this direction by enacting two pivotal Acts: The National Forensic Science University (NFSU) Act 2020.

Under the NFSU Act 2020, the NFSU was established in Gandhinagar, Gujarat, with a clear mandate to promote and provide global standards of learning and research in forensic science. Importantly, the university is empowered to open and establish educational centers in various states and union territories across India. Its mission encompasses enhancing the processes of crime investigation, detection, and prevention in coordination with state governments. Furthermore, it actively contributes to the formulation of policies related to forensic science at the central government level. The detailed mandate and responsibilities of the university are comprehensively outlined in the NFSU Act 2020.

With a view to further enhance the capacity and capabilities of forensic science in India, several key aims and objectives are envisioned:

- i.) **Scientific Aid in Crime Investigation:** Forensic science should provide invaluable scientific support for crime investigations conducted at the scene of the crime.
- ii.) **Evidence Handling:** Implementing standardized procedures for lifting, packing, and forwarding crime case exhibits in a scientific manner following established Standard Operating Procedures (SOPs).
- iii.) **Photographic and Video Documentation:** Capturing physical evidence at crime scenes through photographic and video recordings. This visual data is then compared with databases to identify potential criminals.
- iv.) **Timely Examination of Reports:** Ensuring swift and high-quality examination of forensic reports, making them readily available during the investigation stage.
- v.) **Assisting Courts and Commissions:** Offering forensic expertise to assist courts and commissions of inquiry as needed, without delays.

- vi.) **Database Generation:** Developing comprehensive databases covering various forms of evidence, including fingerprints, footprints, firearms, DNA, tire marks, biometrics, narcotics, wildlife exhibits, hair, currency, coins, passports, and other relevant elements necessary for forensic examinations.
- vii.) **Crime Scene Reconstruction:** Utilizing forensic science for the meticulous reconstruction of crime scenes to aid in investigations.
- viii.) **Technological Advancement:** Encouraging the development and adoption of technological advancements across both traditional and modern branches of forensic science.
- ix.) **Forensic Education:** Providing high-quality forensic science education within universities and professional training institutions to foster a skilled workforce.
- x.) **Preventive Forensics:** Leveraging forensic science to proactively prevent and deter criminal activities.
- xi.) **Disaster Victim Identification (DVI):** Establishing DVI teams and scientific working groups on a zone-wise basis in India for the identification of human remains and bodies during mass fatality incidents.

These aims and objectives underscore the critical role of research and development in the evolution and advancement of forensic science in India. By committing to these principles, India can bolster its forensic capabilities, contribute to effective law enforcement, and ensure a more equitable and efficient criminal justice system.

5. Ethical and Legal Considerations

5.1 Privacy Protections

Advancements in forensic technologies, particularly the acquisition of biometric data encompassing iris scans, retina scans, and DNA samples, introduce substantive privacy apprehensions. While these technological innovations stand as potent instruments in the realm of criminal investigations, they concurrently impinge upon an individual's sacrosanct realm of personal autonomy and privacy entitlements. (Wallace et al., 2014)

As elucidated in the preceding chapter, the Criminal Procedure (Identification) Act of 2022 in India authorizes the collection of an expansive array of measurements and biological specimens for purposes of identification and investigation. Nevertheless, this legislative enactment conspicuously lacks a cogent framework governing the utilization, analysis, and safeguarding of this data. Furthermore, the potential for the misappropriation or undue exploitation

of such data engenders legitimate concerns pertaining to individuals' privacy and the prospective vulnerability to erroneous victimization.

To reconcile the imperative of truth-seeking with the preservation of individual rights, it is incumbent upon legislative authorities to address these apprehensions through judicious means:

Data Protection Framework: India should institute a comprehensive data protection framework that regulates the entire spectrum of forensic data acquisition, preservation, and utilization. This framework must incorporate safeguards meticulously tailored to preserve the inviolability of individuals' privacy prerogatives, precluding the misuse or abuse of their data. Additionally, it ought to delineate the permissible scope of data analysis to forestall any undue overreach.

Informed Consent: The legal framework should integrate lucid directives pertaining to the requisite acquisition of informed consent from individuals prior to the collection of their biometric or other sensitive data for forensic purposes. The imperative of consent is instrumental in ensuring individuals' cognizance of, and concurrence with, the utilization of their data in the context of forensic endeavors.

Data Retention and Deletion: Legislative provisions should expressly specify the temporal parameters governing the retention of forensic data and elucidate the circumstances mandating its expeditious deletion. This not only curtails gratuitous data retention but also circumscribes the potential for untoward data utilization or protraction.

5.2 Regulation of Emerging Technologies

The emergence of forensic technologies, notably Deception Detection Techniques (DDTs), underscores the compelling necessity for rigorous regulation and vigilant oversight to forestall prospective misappropriation and infringements upon rights. As expounded earlier, DDTs such as narco-analysis and polygraph examinations, while potent investigative tools, bear inherent limitations and susceptibility to error. To address these concerns, regulatory frameworks should be meticulously structured to encompass the following facets:

- i.) **Accuracy Standards:** The establishment of stringent accuracy standards for emerging forensic technologies constitutes a foundational imperative. This encompasses the delineation of error rate thresholds, buttressed by an obligation for these technologies to adhere to empirically validated

benchmarks.

- ii.) **Admissibility Criteria:** The formulation of unambiguous criteria governing the admissibility of evidence derived from emerging technologies within the precincts of a court of law is of paramount importance. The veracity and scientific credibility of these techniques must be subject to meticulous scrutiny prior to their incorporation into legal proceedings.
- iii.) **Ethical Guidelines:** The implementation of ethical precepts governing the deployment of emerging forensic technologies is indispensable. These guidelines should encompass considerations for informed consent and the equitable treatment of individuals subject to these techniques, safeguarding their rights and dignity.
- iv.) **Oversight and Accountability:** Robust regulatory bodies or oversight mechanisms should be instituted to supervise the utilization of emerging technologies and guarantee conformity with ethical and legal standards. An integral component of this framework involves the delineation of accountability measures to address instances of misuse or infringements.

As forensic technologies persist in their progression, the imperative of preserving equilibrium between the quest for veracity in criminal investigations and the preservation of individual rights and privacy remains unassailable. Legislative and regulatory paradigms must proffer perspicuous directives encompassing data protection, informed consent, precision benchmarks, and the ethical utilization of emerging technologies to engender a criminal justice system characterized by equity and rectitude.

6. Capacity Building and Training

6.1 Infrastructural Development

Governments bear a pivotal responsibility in the establishment of a conducive infrastructure for the flourishing of forensic justice. This mandate encompasses the allocation of resources for the creation of state-of-the-art forensic laboratories equipped with advanced diagnostic capabilities. In the context of India, while commendable strides have been made in the domain of forensic science, a substantial chasm persists between the available resources and the burgeoning populace. The workload in critical forensic disciplines, including but not limited to DNA analysis, toxicology, biology, document examination, and cyber forensics, stands as an overwhelming challenge. Presently, India grapples with an acute shortage of experts, with only approximately 3,000 reporting officers among a workforce of roughly 4,500 forensic science



personnel. A glaring void exists, as 40% of scientist positions within forensic laboratories remain vacant. (Indulia, 2022). Urgent governmental intervention is imperative to redress this issue, involving the expeditious filling of these vacancies, augmenting the number of laboratories, and the modernization of existing facilities. The amplification of forensic capabilities assumes a position of primacy in facilitating expeditious and accurate criminal investigations.

6.2 Workforce Development

The indispensable role of a well-educated and adept forensic workforce in facilitating the efficacious operation of forensic justice is incontrovertible. Prioritizing training programs and capacity-building initiatives is of paramount significance. Eminent experts underscore the necessity for substantive reforms in forensic science education at the university level. Additionally, comprehensive and continuous training of professionals embedded within the criminal justice apparatus, including police and judicial officers, is imperative. The surging crime rate in India underscores the burgeoning demand for individuals possessing master's degrees in forensic science. To bridge this chasm and engender employment prospects, universities must commit to furnishing quality education in forensic science.

6.3 Public Awareness Programs

Forensic science, often labyrinthine and misconstrued by the general populace, necessitates concerted efforts in public awareness campaigns. The primary objective is to demystify forensic science and engender an augmented comprehension of its role in the pursuit of justice. These programs should not solely serve to educate the public regarding the capabilities of forensic science but also underscore the paramountcy of ethical and legal considerations, encompassing privacy protection. By actively engaging with the public, trust in the forensic justice system can be cultivated, ensuring its transparent and equitable functioning.

In addition to these pivotal imperatives, the National Forensic Science University (NFSU) in India has emerged as a linchpin in capacity-building and modernization endeavors. Through the establishment of Centers of Excellence spanning diverse forensic disciplines and the conception of a model Mobile Forensic Van (MFV) to facilitate modernization, NFSU has wrought commendable progress. The university's contributions extend beyond domestic borders, as it actively

collaborates with other nations, including Rwanda, Namibia, Mauritius, and Zimbabwe, in fortifying their forensic science capabilities. NFSU's initiatives not only redound to the benefit of India but also contribute substantively to the global progression of forensic sciences.

Capacity building, infrastructure development, workforce training, and public awareness programs stand as inextricable constituents of a robust forensic justice system. These endeavors, emblematic of NFSU's initiatives, harbor the potential to transmute forensic science in India and propel its global pre-eminence in this pivotal domain.

7. Forensic Standards Across Borders: The Role of International Collaboration

In the contemporary context of a globally interconnected world, where criminal activities frequently transcend national boundaries, the imperative of instituting international standards governing forensic procedures and the admissibility of evidence assumes paramount significance. This unification of standards serves as the linchpin for fostering coherence and congruence, assuring that forensic evidence collected within one sovereign jurisdiction aligns seamlessly with the practices and expectations prevailing in others. (Forensic Science Standards - Standards Products - Standards & Publications - Products & Services, n.d.)

The development and implementation of international forensic standards are currently undergoing noteworthy progress, with the most salient initiative being the formulation of standards by the International Organization for Standardization (ISO). ISO, headquartered in Switzerland, boasts a membership comprising 162 countries, facilitating the promulgation of globally applicable standards across diverse domains. (Doyle, 2019)

The key tenets underpinning the ISO standard development process necessitate that these standards not only cater to market needs but also draw upon the collective wisdom of global experts. (He & Li, 2021) An imperative facet of this process is the cultivation of standards through a multi-stakeholder framework, underpinned by consensus-based decision-making. For any ISO standard to pass, it requires the affirmative votes of two-thirds of participating member countries, with no more than one-quarter casting negative votes. Of utmost import within this framework is the voluntary nature of compliance with ISO and IEC (International Electrotechnical Commission) standards, unless specifically mandated by regulators. Adherence to these standards is contingent

upon their alignment with the requirements of the countries involved, and they are typically used by industry stakeholders, standard development organizations (SDOs), and regulatory agencies when they demonstrably meet the needs of the implicated nations. (Bouzin et al., 2023)

Rigorous ISO rules govern the development of these standards, obliging all member countries to adhere to a structured framework delineated in the ISO Directives Part 1 and 2. From a forensic perspective, the challenge resides in the delicate balance between crafting standards that provide reliable and consistent results without unduly prescribing the methodology, thus accommodating existing accepted practices. The ISO standard development process unfolds through six discernible stages, as delineated in the ISO Directives Part 2: proposal, preparatory, committee, enquiry, approval, and publication stages. These stages correlate with the development phases of standard drafts that are meticulously reviewed by Working Groups.

ISO Technical Committee TC272, initially constituted as a Project Committee in April 2013, was responsible for crafting ISO/IEC 18385:2016, which pertains to minimizing the risk of human DNA contamination in products used for forensic purposes. In December 2015, it transitioned into a Technical Committee with a broader mandate to develop an array of forensic standards. TC272's scope encompasses the standardization and guidance in the field of forensic science, spanning laboratory and field-based techniques, analysis and interpretation of evidence, reporting of findings, as well as standards tailored for manufacturers of forensic equipment and consumables. In its current configuration, TC272 comprises 23 participating and 18 observing country members, fostering global collaboration in the realm of forensic science standards development. (Bouzin et al., 2023) The committee liaises with organizations such as ILAC and the International Committee of the Red Cross to facilitate broader engagement. (Shepitko & 2021)

While the endeavor to establish international forensic standards is marked by complexities stemming from divergent national priorities, political considerations, language barriers, and geographical distances, the overarching objective remains to produce standards that are not overly prescriptive in methodology but are instead predicated upon recognized best practices. These standards seek to form a coherent and attainable benchmark for quality and risk management in forensic science facilities and accreditation bodies. The ultimate purpose of these standards is to instil confidence in the police and judicial systems that

forensic services are not only fit for purpose but also consistently maintained at an appropriate level of quality. This assurance is a pivotal factor underscoring the adoption of international forensic standards, with the work of ISO TC272 constituting a seminal contribution to this global endeavor.

Conclusion

Forensic justice, characterized by its reliance on empirical evidence over human testimony, plays a pivotal role in the modern criminal justice system. It offers a crucial counterbalance to the inherent vulnerabilities of witness statements. While resource constraints and a lack of awareness have impeded its integration, recent advancements in forensic science, including DNA fingerprinting and voice spectroscopy, hold promise for enhancing accuracy.

Our exploration of the current state of forensic justice has revealed the dichotomy between its immense potential and its prevailing limitations. Resource constraints and a lack of awareness within the criminal justice system have often hindered the seamless integration of forensic expertise. Prolonged cases and delayed justice are the unfortunate byproducts of this existing chasm. Yet, the landscape is rapidly shifting. Recent strides in forensic science herald a new era marked by precision, efficiency, and a broadened scope. DNA fingerprinting, voice spectroscopy, and deception detection techniques have ushered in a revolution, offering unparalleled opportunities to identify culprits and vindicate the innocent with unprecedented accuracy.

India's legislative prowess has illuminated the path forward. The enactment of the Criminal Procedure (Identification) Act, 2022, coupled with the establishment of institutions focusing on Forensic Science education & training illustrates the nation's resolute commitment to the advancement of forensic justice. Nonetheless, challenges loom on the horizon. Privacy protections, regulation of emerging technologies, and the need for a well-educated and skilled forensic workforce call for careful consideration. However, these challenges are not insurmountable, and the path forward is clear. Through stringent regulations, ethical practices, and international collaboration, forensic justice can continue to evolve as a powerful tool in the pursuit of truth and justice.

Forensic justice is more than a concept; it is a dynamic force reshaping the contours of justice. India's progressive steps and global initiatives serve as an inspiration to the world. The path ahead, while challenging, is illuminated by the principles of ethics, the fortifications of regulation, and the power of international cooperation.

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Chapter 3

The Road to Justice: Forensic Chemistry's Policy Recommendations

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Abstract

In modern law enforcement and criminal justice, forensic chemistry is crucial, employing scientific principles and analytical techniques to uncover evidence and ensure justice while upholding human rights principles. The chapter provides a comprehensive overview of the field, its diverse sub-domains, and the challenges and opportunities it offers in the current context. It delves into the critical functions of forensic chemists, including crime scene investigations, evidence analysis, drug investigations, arson investigations, petroleum product analysis, environmental forensics, explosives and explosion investigations, toxicology analysis, and combating environmental crimes. It also addresses the problems currently facing forensic chemistry, such as backlog/pendency, limited resources, quality of evidence, complicated mixtures, new substances, scientific advances, data management, legal and ethical concerns, presentation in court, public perception, and the need for interdisciplinary and cross-border collaboration. The chapter offers policy recommendations, including data management, quality control, research funding, interdisciplinary collaboration, capacity building, and international collaboration, to improve forensic chemistry's capabilities, reduce case backlogs, and ensure impartial justice administration.

In conclusion, the implementation of these recommendations will address the challenges and increase the effectiveness of forensic chemistry, facilitate investigations, and improve justice enforcement.

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Introduction

Forensic science is a complex field of science devoted to utilizing scientific principles and techniques to resolve crimes, ensure justice, and protect human rights. Forensic Chemistry utilizes fundamental principles of chemistry to determine the chemical characteristics of substances, providing valuable information about the crime to law enforcement authorities and the criminal justice system, thereby safeguarding human rights. This science involves thoroughly examining physical evidence, uncovering key leads, connecting suspects to crime, and providing irrefutable scientific evidence that supports justice. Forensic chemistry involves a variety of sub-domains, including drug analysis, poison analysis, explosives and post-blast analysis, arson investigations, petroleum product analysis, environmental forensics, and many more, all of which help solve crimes and ensure public safety and uphold the principles of equity and accountability within the legal system.

Crime Scene Investigation:

Forensic chemical experts assist in the identification, collection, and preservation of evidence at crime scenes and can provide investigators with suggestions on how to search chemical evidence and identify the various substances found at a crime scene. This ensures that evidence is admissible in court and is subject to legal scrutiny.

Evidence Analysis:

Forensic chemical experts analyze a variety of physical evidence, such as drugs, toxic substances, bribe traps, arson accelerants, petroleum adulterants, cosmetic products, and explosives. The chemical composition of these substances can provide necessary insights into a case, allowing investigators to establish links between suspects and the criminal.

Drug Enforcement Agencies:

Forensic chemistry involves analysis of controlled/prohibited drugs and psychotropic substances, identification and quantification of seized drugs, and determination of purity in the context of drug-related crimes. This data is important for prosecuting drug traffickers and effectively implementing drug laws.



Fire and Arson Investigations:

Fire and arson investigation involves forensic examination of residues and accelerants (petroleum products such as gasoline, diesel fuel, kerosene, turpentine, butane, isopropyl alcohol, and various other flammable solvents) to determine the cause and origin of fire. This can help investigators to investigate whether the fire was deliberate or accidental in nature. Investigation cannot only help victims to get insurance claims but also the insurance companies to nab false property damage claims.

Petroleum Products Analysis:

Forensic chemical examiners evaluate the quality of petroleum products, help determine source and composition, and assist in adulteration, fraud, or disputes. They also aid in environmental assessments, particularly in examining oil spill cases, by providing important data to identify sources of contamination and guide remediation efforts.

Explosive and Post-blast Investigation:

Forensic chemical experts collect and examine the post-blast residue and can provide investigators with valuable information about the type of explosive, parts of explosive devices, the direction and point of the explosion, and even the nature of the explosion.

Environmental-Related Crimes:

Forensic chemistry also contributes to investigations related to environmental crimes, such as the illegal release of hazardous effluents, pollution, and illegal disposal of hazardous materials.

Toxicological Analysis:

Forensic chemistry involves the examination of harmful substances in human and animal bodies to determine the presence of drugs, alcohol, poisons, toxins, or xenobiotic substances. Chemical examination can provide meaningful evidence in cases of drug overdose, drug intoxication, drunken driving, and poisoning (such as suicides, homicides, and accidents).

Current Landscape of Forensic Chemistry

Forensic chemistry helps law enforcement identify suspects, set timelines, and reconstruct events by analyzing physical evidence in the form of chemical

substances found at crime scenes. This analysis can lead to the conviction of perpetrators and the exoneration of innocent people. Regardless of their role, there are several challenges in forensic chemistry that forensic chemists and law enforcement agencies.

Backlog/Pendency of Cases:

One of the biggest challenges for forensic analysis in India is the lack of trained staff. Currently, there are only a few hundred qualified forensic chemical experts in India and the demand for their services far outstrips the supply. This has left many forensic laboratories understaffed and exhausted resulting in a significant backlog/pendency of cases. Another challenge for forensic toxicology in India is the lack of standardized procedures. NABL Accreditation status of many forensic laboratories is still noncompliant leading to issues with the reliability and accuracy of the results, and ultimately a delay in obtaining critical evidence.

Limited Resources:

Forensic chemistry requires specialized equipment and highly skilled personnel. However, budget constraints and insufficient manpower make it difficult to allocate the necessary resources and maintain state-of-the-art forensic laboratories.

Quality of Evidence:

The quality and manner of preservation of evidence collected at the crime scene plays an important role in determining its legal significance. Contaminated or poorly preserved samples can affect the accuracy and reliability of forensic analysis. Sample cold storage facility is not available at many forensic laboratories leading to sample degradation.

Complex Mixtures:

Forensic evidence is often mixed, adulterated, or contaminated with other compounds, making it difficult to analyze, identify, and quantify.

Emerging Substances:

With the development of new technologies, new medicines, and psychotropic substances regularly come into the market, so upgradation of laboratory and knowledge is required for the identification and handling of these novel substances.



Scientific Advancements:

Keeping abreast of the rapidly evolving scientific advances in forensic chemistry requires ongoing investments in education and technology that require a dedicated budget for training programs.

Data Management:

The volume of data generated by modern forensic techniques such as high-end mass spectrometers and spectroscopy techniques can be significant. However, to process and analyze this information effectively, an efficient data management system is required.

Legal and Ethical Concerns:

The admissibility of forensic evidence in court can be a contentious issue, with debates over the validity and reliability of the methods and analytical techniques used having direct implications for human rights through the fairness of legal proceedings.

Courtroom Presentation:

Effectively communicating complex scientific knowledge to judges and juries who may not have a scientific background can be challenging. Ensuring that forensic evidence is presented clearly and convincingly is critical to its effectiveness in court.

Public Perception and Trust:

Ensuring the integrity and reliability of forensic analysis is essential to maintaining public confidence in forensic science. High-profile cases of error or misconduct can have repercussions.

Interdisciplinary Collaboration:

Effective coordination between experts from different disciplines is essential for comprehensive investigations. Collaboration with other forensic disciplines such as biology, physics, ballistics, DNA, and cybersecurity leads to better understanding and conclusions.

International Collaboration:

Coordinating forensic standards and practices across borders can be a complex effort, particularly in cross-border crime cases where law enforcement agencies may need to work with overseas collaborators.

Key Technological Advancements

The key technological advancements in analytical instrumentation have significantly empowered forensic scientists in the crucial task of analyzing emerging chemicals in today's complex landscape while fundamental techniques like UV/VIS, FTIR, TLC, HPLC, GC-FID, and GC-MS have their place in forensic chemistry and continue to be valuable tools, the implementation of advanced technologies is essential to meet the demands of modern forensic investigations. Advanced technologies such as High-resolution mass spectrometry (HRMS) and tandem mass spectrometry (MS/MS), coupled with gas chromatography (GC), liquid chromatography (LC), and inductively coupled plasma (ICP), provide sensitivity, specificity, speed, and capabilities to address the multiple challenges posed by new chemicals, even at trace levels, in complex mixtures and evolving criminal activity, ultimately contributing to effective justice and public safety.

For example, to support drug and toxicology studies, it is strongly recommended to use LC/MS-MS and GC/MS-MS, especially with Multiple Reaction Monitoring (MRM) or Selective Reaction Monitoring (SRM) functions. These advanced technologies play a crucial role in identifying and quantifying emerging drugs and toxins in biological samples, providing a powerful tool to combat illicit drug activity. In addition, GC-HRMS and LC-HRMS enable the precise identification of novel psychoactive substances (NPS) and designer drugs, often in tiny amounts. In addition, ICP/MS-MS is utilized with its advanced features such as triple quadrupole configuration and collision/reaction cell technology. This technology proves invaluable in cases of environmental pollution or illicit drug production where trace metals can be a critical factor.

Policy Recommendations

Data Management and Sharing:

As India continues to modernize its forensic capabilities, database management and sharing will continue to be at the forefront of these advances, particularly in forensic chemistry in solving crimes and delivering justice.

In a diverse country like India, where numerous forensic laboratories operate independently, effective data management and sharing are paramount to ensure the integrity and efficiency of forensic investigations. In general, forensic laboratories frequently encounter similar cases. Effective data exchange can significantly reduce duplication of work and resources. Instead



of multiple labs independently analyzing the same evidence, sharing data can streamline processes and improve overall efficiency.

Laboratory information management systems (LIMS) support data management and records. LIMS can help ensure that all data is accurately captured, securely stored, and easily accessible. Adequate funding and training are critical to the effective implementation and maintenance of these systems.

Developing a comprehensive legal and ethical framework for data sharing is critical. This framework should include protocols for obtaining consent, protecting privacy, and ensuring data security. By adhering to these guidelines, laboratories can navigate the complex landscape of legal and ethical concerns while promoting the sharing of information.

Quality Control and Standardization:

Quality Assurance (QA) and Quality Control (QC) and standardization are of paramount importance in the field of forensic chemistry.

Governments and relevant law enforcement agencies should work with forensic science experts to maintain quality according to national and international standards such as BIS, ASTM, ISO 9001:2015, and ISO/IEC 17025:2017 (NABL Accreditation) for forensic chemistry. These standards cover a wide range of procedures, from evidence collection to analysis and reporting.

Laboratories should implement robust QA/QC protocols at every stage of analysis. This includes the use of positive and negative controls, certified reference materials, calibration standards, and proficiency testing programs to ensure the accuracy and reliability of results.

Periodic audits and assessments of forensic laboratories by independent bodies can help identify areas where QA/QC and standardization need improvement.

Forensic personnel should undergo mandatory training in QA/QC and standardization practices. Continuous education and training programs should be offered to keep forensic scientists updated on the latest developments in the field.

Laboratories should be open to feedback and committed to making necessary changes.

All laboratory procedures, from evidence handling to analysis, should be thoroughly documented and standardized. This ensures that every step of the process is transparent and can be reproduced, if necessary.

The establishment of a separate and dedicated accreditation body for forensic sciences in India promises tremendous progress in this area. Such a board can serve as a key leader, tailoring their support and guidance to the specific needs and geographic locations of different laboratories across the country. Offering specialized accreditation services, can not only improve the quality and reliability of forensic analysis but also promote consistency and standardization, ultimately enhancing the credibility and effectiveness of forensic investigations across the country.

Research and Development Funding

To encourage advances and improvements in the field of forensic chemistry, it is critical for governments and regulatory agencies to allocate significant funding to research and development (R&D) initiatives.

Modern technology is essential for conducting advanced research and analyses in forensic chemistry. Governments should allocate a dedicated budget for R&D. Currently only a few organizations such as DFSS and BPR&D award research grants in forensic sciences and allied. The former agency provides grants in forensic sciences while the later issues grant for research related to criminology or forensic psychology. Recent years have seen a declining trend in overall grants with inadequate budgets, resulting in an outdated research infrastructure. This funding should be consistent and sustained over the long term, providing researchers with financial stability.

Funding agencies such as DST, CSIR, ICMR, ICAR, DRDO, and UGC - National Innovation and Startup Policy (NISP), National Research Foundation (NRF) should join forces to work with forensic institutions and government/central/UT forensic laboratories to allocate more research funds to expand government institutions support financially. It is also suggested that a research fellowship scheme for students and professionals working in forensic sciences should be started either on a merit basis or examination-based. This will motivate the masses to work for the upgradation of forensic methods.

Flexible and adaptable funding opportunities should enable the support of projects that go beyond traditional disciplinary boundaries. This flexibility allows researchers to explore new approaches and methods to produce more and more breakthrough research.



Advanced forensic techniques developed through research and development reduced the backlog/pendency due to old, lengthy analysis procedures and assisted in the re-evaluation and resolution of unsolved cases, bringing closure to victim's families, and ensuring justice.

Interdisciplinary Collaboration

Collaboration with experts from different disciplines can lead to the integration of innovative technologies and techniques into forensic chemistry with the aim of facilitating the exchange of knowledge, data, and expertise.

Research collaboration between government agencies, academic institutions, and private sector organizations needs to be encouraged. Cross-sector partnerships can leverage resources and expertise to drive innovation. Such cooperation not only provides funding but also brings interdisciplinary expertise in various fields and results in the development of cutting-edge analytical tools and approaches such as nanotechnology, lab-on-chip, etc.

Collaboration with legal experts and policymakers can help bridge the gap between scientific research and the legal system and ensure that forensic evidence is used effectively in court to protect human rights.

Collaboration with data scientists and statisticians can improve data analysis methods and lead to more accurate and meaningful interpretations of forensic evidence.

The creation of a specialized Poisons Information Centre for forensic toxicology is strongly recommended. Such a center would serve as a vital resource for forensic toxicologists, law enforcement agencies, and healthcare professionals. It would expedite the identification of toxic substances and assist in poisoning investigations. Additionally, it would improve public safety by offering guidance during toxicological emergencies and advancing research on emerging toxins and their effects.

Multidisciplinary approaches can help unravel the intricacies of complex cases and provide critical insights for case resolution.

Capacity Building and Training

Capacity building and training are essential components to ensure the competence, reliability, and effectiveness of forensic scientists and laboratories. These initiatives contribute significantly to the field of forensic science and the criminal justice system.

Infrastructural Development

Investing in the **upgradation of laboratory infrastructure** enables the integration of modern instruments and technologies such as mass spectrometers, gas chromatographs, and advanced microscopy systems, enabling forensic scientists to perform analyses with greater sensitivity, accuracy, and efficiency, and significantly reducing the time required to perform analyses.

Investing in state-of-the-art laboratory infrastructure not only increases effectiveness but also brings significant **economic and societal benefits**. It accelerates case resolution, reduces the case backlog, and eases the burden on the criminal justice system. By enabling timely and accurate analysis, infrastructure improvements increase the likelihood of arresting and convicting criminals, deterring potential offenders, and ensuring justice is served.

Workforce Development

Workforce development in laboratories is essential to ensure that forensic scientists are proficient in using cutting-edge technologies.

The accuracy and reliability of forensic analysis directly affects case results. Proper training in advanced techniques increases the precision of analyses, and reduces the risk of errors, false positives, and contamination, thereby ensuring the integrity of evidence.

Develop specialized training programs that focus on specific advanced techniques, such as mass spectrometry, chromatography, spectroscopy, and microscopy. These programs should cater to different levels of expertise, from beginners to experienced forensic scientists.

Forensic scientists trained in advanced techniques contribute to more effective investigations, aiding law enforcement agencies in solving complex cases and preventing future crimes.

Proficiency in advanced technologies enables forensic laboratories to process evidence more quickly, expediting case resolution and alleviating case backlogs.

Encourage forensic personnel to attend workshops, seminars, conferences, and hands-on training to keep up to date with the latest developments in the field.



To check the efficiency of the scientific staff and capabilities of laboratories routine proficiency testing is encouraged.

It is suggested that a national body conducts an exam every five years to check the knowledge and competence of scientific staff. Similarly, certification can be issued with a validity of five years. This will create positive competition among the scientific staff.

International Cooperation

Coordinating forensic standards and practices across borders can be a complex effort, particularly in cross-border crime cases where law enforcement agencies may need to work with foreign collaborators. Therefore, continued international collaboration in the field of forensic chemistry and toxicology is supported through collaborations with organizations such as the United Nations Office on Drugs and Crime (UNODC), the International Association of Forensic Toxicologists (TIAFT), and the American Academy of Forensic Sciences (AAFS) and many other international organizations will strengthen forensic capabilities worldwide and contribute to global security and human rights protection. The Organization of Scientific Area Committees (OSAC) for Forensic Science is an initiative by the National Institute of Science and Technology (NIST), USA for the uniform standardization of methodology used in forensic sciences. The same model can be adapted to uniformly implement the standard methodology in forensic laboratories across India. These global bodies facilitate the sharing of knowledge, harmonize best practices, and strengthen forensic skills worldwide. By fostering partnerships and sharing expertise, nations can work together to fight cross-border crime, share forensic data, and improve forensic standards. Such collaboration increases the credibility of forensic evidence in international courts, strengthens investigations, and ultimately contributes to global security and justice. It underscores the importance of a united front in addressing cross-border challenges and advancing forensic science on a global scale.

Conclusion

A comprehensive plan is suggested to successfully overcome these obstacles. To reduce redundant data entry and increase efficiency, forensic labs should first establish effective data exchange channels. The adoption of reliable Laboratory Information Management Systems (LIMS) should be supported by frameworks for sharing data that are both legal and ethical. Second, to ensure compliance with national and international forensic chemistry standards, strict quality control protocols and ongoing personnel training should be implemented. Third, adequate

and ongoing funding for research and development is required to support the development of new forensic methods and tools. Fourth, to promote innovation, cooperative projects between public and private sector organizations should be supported. It is recommended that forensic toxicology experts, data scientists, statisticians, and a specialized Poisons Information Centre be incorporated into the framework. Last but not least, investments in contemporary laboratory infrastructure should be made, and the workforce training program should be specialized.

In conclusion, these suggestions strengthen forensic chemistry's capabilities, promoting quicker, more impartial investigations and the administration of justice. This comprehensive strategy tackles forensic chemistry's challenges and reaffirms the fundamental importance of our legal system.

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Chapter 4

Organizational Improvements

Dr. S.K. Jain¹

Technological up gradation:- The cycle of science, innovation and growth is the rationale in Forensic Science. Contemporary forensic institutes operate state-of-the-art laboratories where evidence is studied with modern instruments. Without this often high-tech and expensive equipment, the forensic expert would not be able to generate the forensic findings that so often are of vital importance to solve a crime and assure high-quality rulings in a court of law. In view of this it is very important that Forensic Science Labs across the country upgrade themselves in terms of technology after regular intervals and adopt new development of basic science in forensic science labs.

Forensic technology has become the most expedient tool nowadays by being a great source of providing legal aid to the criminal justice delivery system. An updated forensic technology can eradicate nearly all the loopholes to an extent which used to be a time taking process in investigating a criminal case. In order to deal with rapidly changing crime scenario, all FSLs should adopt newer techniques to solve the crime in technological and accurate way. Cyber /Computer Forensic, DNA profiling and Narcotics have established new dimensions in forensic investigation. With the help of these technologies, many critical cases of sexual assault, paternity and POCSO have been resolved.

To help the judicial system it is very crucial to adopt new techniques, establish new divisions like Cyber /Computer Forensics, Narcotics, DNA, Forensic Engineering, Forensic Intelligence to solve the cases in minimum time so that culprit get punished immediately and the victims get justice in timely manner.

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The Government has also decided to strengthen DNA analysis labs, Narcotics and Cyber Forensic Units in all the States and Union Territories through its ambitious Nirbhaya Fund scheme. A State of the Art DNA, lab under the Nirbhaya scheme has already been established at Central Forensic Science Laboratory, Chandigarh.

Similarly to combat the white collar crime, through the scheme of CCPWC Division, MHA; DFSS established state of art National Cyber Forensic Laboratory (E) at CFSL Hyderabad. This laboratory is established with the aim d to build up a high-end Forensic Smart Server with the provision of scalability which would act as a centralised repository of cyber crime case data for indexing and storage apart from processing.

By adopting new techniques, trained manpower and opening new divisions forensic scientists will be able to deter the heinous crimes, including the crimes committed on women, speedily and accurately. forensic science provided a strong scientific support system to the courts of law for taking a swift decision. This kind of swift implementation of judicial process will not give criminals any opportunity to escape justice.

2. R&D Wing in CFSL/FSLs:- forensic sciences need to change in order to place themselves on an appropriately secure foundation in the 21st century. The traditional forensic sciences in general, and the pattern identification disciplines, such as fingerprint, firearm, tool mark and handwriting identification evidence in particular, do not currently possess – and absolutely must develop – a well-established scientific foundation. This can only be accomplished through the development of a research culture that permeates the entire field of forensic science. A research culture, must be grounded in the values of empiricism, transparency, and a commitment to an ongoing critical perspective. The forensic science disciplines need to substantially increase their commitment to evidence from empirical research as the basis for their conclusions. Sound research, rather than experience, training, and longstanding use, must become the central method by which assertions are justified. Keeping this in view, it is essential that R&D wing should be created in each CFSL/FSL to carry out research in the emerging fields of forensic science.

In the recent judgement of Karnataka High court also, the Hon'ble court in case WP NO.2739 OF 2021 *High Court of Karnataka vs the State of Karnataka on 13 August, 2021* clearly issued directions in following manner:-

'It is also brought to the notice that there is no research and development unit in any of the FSL and therefore, it is required that such a Wing is established. We direct that a Research and Development Wing be established in the SFSL, which shall look into, analyse and recommend the introduction of new sections in the SFSLs, as also RFSLs, the latest equipment that is required to be procured, as also to WP NO.2739 OF 2021 formulate guidelines and/or Standard Operating Procedure as regards collection, transportation, storage and processing of samples. The said Wing could also formulate and develop the format of the reports that are to be submitted, as also to identify any refresher courses, training and or the like which are required to be made available to the officers of the FSLs both at the SFSL and RFSLs and provide such training through proper and suitable resource personnel. In this regard the said Wing could also obtain study and recommendation reports from Expert Organisation.'

3. Deployment of Mobile Forensic Van + Forensic Officer+ Driver cum Photographer in every Police Station:

- **Mobile Forensic Van:** Should have all necessary equipment's required to collect the evidentiary value material from the scene of crime. It should have uniform design with general specifications. DFSS has also developed specifications of Mobile Forensic Van with IoT (Internet of Things) enabled Forensic Evidence Management System.
- **Forensic Officer:** - Crime investigation is an important task at Police Stations. Generally Head Constable or Inspectors assigned the task of crime investigation. These officers do not possess specialized knowledge and skills of forensic sciences hence, the investigation or exhibits deteriorate due to lack of expertise. Because of this phenomenon, the evidence is either not collected properly or not packed properly resulting in loss of its evidentiary value. It is, therefore, pertinent that forensic investigations are not left to the field officers but officers with background of forensic sciences in the Police Stations to take up this job exclusively. Further, an expert with qualification of M.Sc. (Forensic Science) can be attached to the police stations who will accompany the crime scene investigation team mandatorily.
- **Driver cum Photographer:-** These vans should have one or two drivers who possess qualification of driving professional vehicles with additional qualification of photography of crime scene to cater the requirement of both the jobs.

4. Implementation of ICJS :- The use of information technology in the judicial domain started with the preparation of 'National Policy and Action Plan for

Implementation of ICT in the Indian Judiciary' by the e-Committee of Supreme Court of India. The Inter-operable Criminal Justice System (ICJS) is an initiative of the e-Committee to enable seamless transfer of data and information among different pillars of the criminal justice system, like courts, police, jails and forensic science laboratories, from one platform. It has mainly three features:-

Work flow based

Automates the complete work flow of forensics Labs from registration to dispatch of reports.

Data Sharing

Data and report sharing with other pillars like police and courts.



Dashboard reports

Provides statistical and status information about the registration, report readiness and dispatch of reports.

Many forensic science labs yet to include themselves in ICJS system, which is very essential for transparency. The merits of ICJS is

- It reduces errors and time taken in sharing of necessary information between different pillars of Criminal Justice system, thereby enabling speedier delivery of justice to the common man
- It also helps in improving investigation quality by leveraging the analytics inbuilt in the platform.
- The ICJS platform is an effective tool for the case and court management, as all the relevant information of a case will be available in real-time for use by the courts.
- Compliance of judicial orders and summons can also be achieved expeditiously, ensuring effective time management.

5. Quality Assurance and Quality control: Presently there are very few NABL accredited laboratory are there in the country. Accreditation assesses a forensic lab's capacity to generate and interpret results in a particular forensic discipline and helps to ensure an ongoing compliance to industry and applicable international standards. The central and state labs are required to do the needful to get the accreditation as per ISO/IEC 17025 guidelines. Directorate has prepared and published one Quality Manual for ease of all forensic Institutions. The same



is available free of cost on DFSS website i.e. www.dfs.nic.in/downloads

6. Standardization of Forensic Reporting:- Forensic science is a critical element of the criminal justice system. Forensic scientists examine and analyze evidence from crime scenes and elsewhere to develop objective findings that can assist in the investigation and prosecution of perpetrators of crime or absolve an innocent person from suspicion. DFSS as per its mandate, took initiative to bring uniformity in the process of forensic examination of crime case exhibits of various forensic disciplines. DFSS/MHA formed Scientific Working Groups, comprising eminent forensic scientists of the CFSLs for each forensic discipline to compile forensic analytical techniques in the form of Laboratory Procedure Manuals and Standard Operating Procedures documents. The manuals of Biology, DNA, Chemistry, Narcotics, Toxicology, Crime Scene a Computer, Mobile Forensics, and speaker Identification and developed by Directorate of Forensic Science Services are available on its website i.e. www.dfs.nic.in/downloads

7. Standard list of equipment for FSLs:- This Directorate published a list of equipment required for establishment/upgradation of forensic science divisions; this can be used as annexure in the NHRC Book. Link is as follows:-http://www.dfs.nic.in/pdfs/standard%20equipment%20list_unlocked.pdf

8. Enhancement of financial powers of the Directors/Heads of the Central and State FSLs:-State and centre must kept separate provisions of budget for strengthening of forensic science services in the country. The Heads of the laboratory should be given more financial powers so that decision making and accountability could go hand in hand. The Director of forensic science laboratory should have adequate financial powers to procure kits and consumables and necessary M&E so that case and research work could not be hampered.

9. Training /certification: All forensic scientists should become certified in the areas in which they work. Analysts should receive their first certification within 2 years of their joining of services. He/she must be provided training in, communication skill, personality development, general forensic science, basic knowledge of case examination alongwith attachment with the laboratory to handle the real cases. After getting the certification he will be eligible to do case examination.

Provision of training should be before any promotion to the next level followed by test to be passed by every expert.

10. Standardization of Forensic Education: Presently so many universities are teaching Graduate and PG level courses of forensic science. However, the contents of syllabus in these universities are not uniform. A committee of academicians and forensic scientists are required to be constituted to finalise the uniform syllabus and curriculum of UG and PG level. Preference is required to be given to the students holding PG degree/diploma with Forensic Science. This committee may review the same after every three years regularly.

11. Introduction of F.R.D.A, (Forensic Regulatory Development Bill)
To establish a Forensic Sciences Development and Regulatory Authority and to provide regulation, standardization and accreditation of forensic science services, and certification of forensic science practitioners, and for matters connected therewith or incidental thereto. Presently, private labs across the country offer questioned document, cyber forensics, fingerprinting, audio-video forensics, cell phone forensics, forensic DNA & biology, ballistics, and toxicology among other services, but without accredited credentials - both of the lab and the 'experts' conducting them – which can jeopardize the entire criminal jurisprudence.

Most of the services also need high-end equipment and permission from the state. To regulate these labs and for transparency it is high time to bring Forensic Regulatory Authority Bill as is done in other customer oriented services. This authority may have right or permission given by this Authority to an accredited forensic science service provider to offer or undertake forensic science services. This authority may be headed by a Chairperson of DG level or retired Chief Forensic Scientist and twelve other Members, of whom at least three shall be women, to be appointed by the Central Government.

Chapter 5

Technological Upgradation

Keshav Kumar (IPS retd.)¹

Introduction

The Directorate of Forensic Sciences services was created in the year 2002 by the Ministry of Home Affairs, Govt. of India, after bifurcation from BPR&D, based on the recommendations of National Human Rights Commission and Padmanabhaiah Committee on Police Reforms. The Gazette notification to this effect was issued by MHA vide its Order no. 25011/41/2001-GPA.II/PM-II on December 31, 2002. It is headed by the Director of Forensic Sciences. The mission statement of the Directorate of Forensic Science Services is to render 'High quality and credible forensic services' to justify delivery system.

Current status of forensic equipment used

The current national legal frameworks are incapable of addressing the rapidly evolving 'modus operandi' associated with crime. The duration of any investigation cannot be estimated. As time passes, the chances of solving a case reduces as the memory of eye-witnesses, victims and suspects gets susceptible. During investigative interviews, a number of factors affect the responses of the witness, victims and suspects. To determine the validity of the statements provided by the witness, suspect or victim and to detect false confessions or allegations, different forensic investigative techniques have also been developed. Forensic Psychological investigative methods include Narco Analysis, Suspect Detection Test, Statement Analysis, Layered Voice Analysis, Polygraph, Eye Detect System and Brain Electrical Oscillation Signature Profiling. These are used as corroborative evidence to aid in the process of investigation.

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I. Forensic Psychology Division

Forensic Investigative Tools. Following are the currently the Available Tools:

Brain Electrical Oscillating Signature Profiling (BEOS) Old-classic model

Brain Electrical Oscillation Signature Profiling (BEOS) is a non-invasive technique with a significant degree of sensitivity and a neuro-psychological method of investigation which is also referred as Brain Mapping or Brain fingerprinting. It has been successfully used as a scientific aid for forensic formulations and investigations in hundreds of cases. It is considered to be the most humanitarian and dignified method. It is a technique which can detect the participation of the suspect in a crime by electing the brain impulses. This tool measures the changes in the electrical activity of the brain associated with the existence of the knowledge of crime and extracting a signature of electrical oscillation from the overall electrical activity of the brain when provoked by different probes. It was developed in the year 2003, by Professor Emeritus Champadi Raman Mukundan, former Director of School of Behavioural Science, National Forensic Sciences University and also the founder of the Clinical Neuropsychology department and set up a Neuropsychological Laboratory for cognitive electrophysiological experiments at NIMHANS, Bangalore. BEOS is based on the encoding of an action during participation of an event, storage and retrieval of the memory. The BEOS profiling measures the remembrance of the experiential Knowledge (EK) which is facilitated by awareness of contextual details and emotional arousal present during the crime (Mukundan, 2007). With the help of appropriate probes, the electrical activity related to remembrance can be evoked which are also called the 'signature of the experience'. The probes are used to trigger the remembrance of specific autobiographical episodes and measures the neural activation generation using electrophysiological changes. This technique is



Image of BEOS Administration

utilized at the Directorate of Forensic Sciences since 2003. Legal mandate from court. At present, the only fully functioning lab across the country is DFS, Gandhinagar. A court mandate is a compulsory requirement for its execution under any DFS.

Advantages

- Non-invasive technique and most humanitarian technique.
- Made in India
- Instant Auto-generated reports
- Will be able to find the extent of involvement of a person in the crime, may it be a primary offender, eye-witness or conspirator.
- The presence of experience of taking part in an activity is elicited without the subject having to give any verbal or non-verbal response in the testing situation. Right to remain silent is protected.
- Language independent

I.1.1.1 Specific to which crime

Several hundreds of cases (Murder, POCSO, Homicide, Criminal Attempt, Conspiracy, Theft crimes, Robbery, Forgery, Kidnapping, Sex Crimes) have been successfully investigated using the procedure, which has helped to understand the specific roles played by participants in each episode.

To name a few, it has been used in Nithari Serial Killing Case, Unnao Rape Case, Kotkhai Minor Rape and Murder Case, Arpita Murder Case, Gauri Lankesh Murder Case, etc. It has not only been used to nab the accused but also to prove innocence.

BEOS (portable version): It is a convenient alternate to the existing classic model of BEOS Profiling which can be moved to any place based on requirement.



BEOS Image Classifier: This instrument is the latest development especially for people who are caught in the act. In order to understand who are the people who have participated in the crime. It requires to just mention the name of the reference point (vague code word) putting the code word. Bangladesh intelligence use group of pictures (related neutral unrelated) rule in randomization and analyze the response of the suspect. It classifies the images and shows whether or not the subject has recognized the picture. It is mainly used for Intelligence gathering. It visually grasps the images. It is in use for more than 6 months to this day outside India. It works on the principle of Portable BEOS although it must be ensured that there exists no visual distraction.

Suspect Detection System

Classic model

In the year of 2004, Suspect Detection Systems Ltd. (SDS) was founded with a mission to prevent crimes and terrorism even before it gets executed by detecting hostile intents. The Israeli Chief Scientific Office and the US Transportation Security Administration are credited for the research and development of the technology. At present SDS enjoy the status of the only established noninvasive technology which proved to be able to differentiate between “guilty” and “innocent” examinees in 5 minutes test with low false alarm. The present SDS solution – The COGITO system, developed by SDS, is an interrogation and screening system for identifying the potential suspects and obtaining intelligence during investigation. The COGITO is an automated decision-making system which is capable of collecting and analyzing psychophysiological indications and cross checking it with available information. It is designed to be fully automated and no experts are required in order to operate the system. The functionality of SDS includes some basic aspects. Firstly, it is used for screening, i.e. detection of suspects out of group of people. Secondly, it is used for interrogation, i.e. collecting information from suspects or witnesses. Thirdly, it can be used as an additional screening questionnaire which can be presented to an examinee who is already in the data base. This method uses ‘Guilty Knowledge Test’ method or the Concealed Information Test (CIT) instead of the control question technique which ensures the system to achieve results as low as 4% false-positive. The underlying assumption of using GKT is that when an individual performs an “emotionally affecting” act involving guilt or fear (which is only known to her/him and the investigator), her/his reaction towards a specific event-related stimulation will be different than that of a non-involved individual. The specific

details related to crime like the weapons used, time of murder, place of murder etc., are known as the Relevant Stimulating Objects (RSOs), which is only known to him and IO. Presenting the murderer with these RSOs will engender a different and detectable reaction than that of an innocent person who has no awareness about the relevance of these specific details. The SDS technique records the physiological phenomenon, i.e the Galvanic Skin Response (GSR). The Electrodes used for obtaining the recording of GSR are fastened to the papillary ridge side of the first joint of the forefinger and the third finger and the palmar and dorsal surfaces of the left hand through which an imperceptible current of electricity is passed. The Guilty Knowledge test or the Concealed Information Test involves a series of multiple-choice questions, each having one relevant alternative and several irrelevant alternatives, chosen so that an innocent suspect would not be able to discriminate them from the relevant alternative. As opposed to innocent person, the guilty person will constantly react to the relevant questions. Hence, the questionnaire designed focuses more on the concealed information. Suspect Detection System was introduced at Directorate of Forensic Science, Gandhinagar, Gujarat in the year 2009. The administration of SDS does not require a court permission rather it can be executed by the permission of the State Police or the IO. However, the consent from the suspect is mandatory. The process involves developing 6 sets of scenarios with 6-7 questions. Depending on the responses made at the end of 4 set of questions by the suspect, the system decides if the subject is a suspect or non-suspect. In case of 'suspect', the system will automatically present additional 2 sets of questions in order to reduce the case of false positives. Both voice and video of the suspect is recorded by the system.



Advantages

- Multi-lingual automated system used both for screening or flagging suspects from mass and as an investigation tool revealing the concealed information from suspects.
- It is a rapid interrogation process and if administered immediately after considerable time of period of the crime, it can provide essential leads in the direction of investigation.
- Non-invasive technique.
- Hon'ble court permission is not required for administering the test, however, examinee's consent is mandatory.

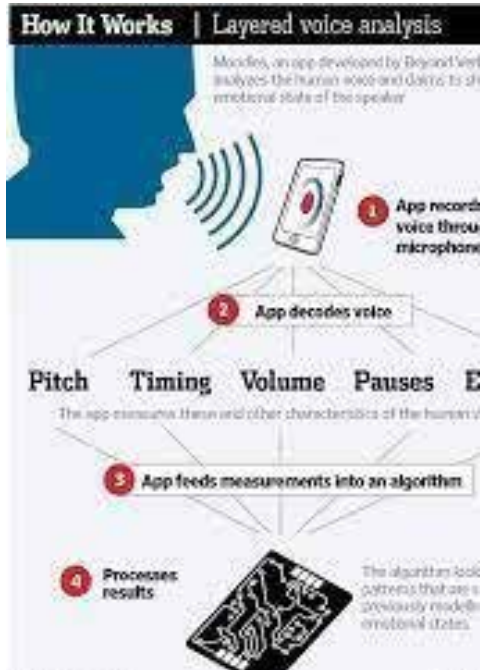
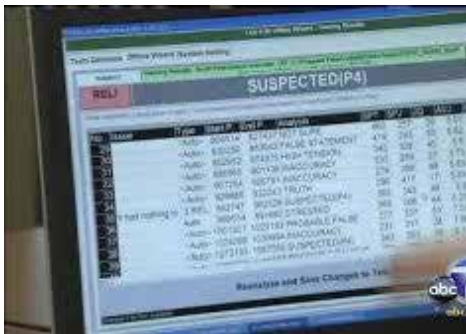
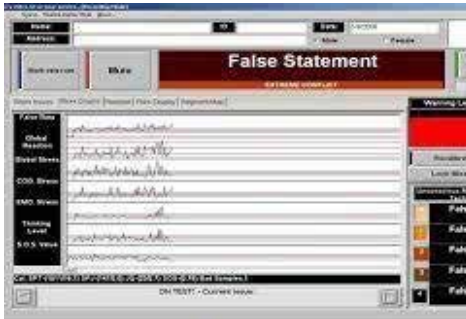
I.1.2.1 Specific to which crime

It is used as a screening tool where there are more number of suspects and we need to filter from the pool of suspects. It has been used in cases of White collar crimes, Murder, POCSO, Homicide, Criminal Attempt, Conspiracy, Theft crimes, Robbery, Forgery, Kidnapping, Sex Crimes.

Layered Voice Analysis Classic model

Layered Voice Analysis (version 6.50) is a professional/security level emotion analyzer based on Nemesysco's unique LVA technology which came into operation since 2012 and has proved helpful in providing quick and reliable results for the crime investigation since then. It is designed for professional investigators, governments, security organizations, police, military and immigration authorities. The LVA technology enables a quick and effective decision-making process based on any available human speech data. It identifies various types of stress, cognitive processes and emotional reactions that expose the emotional profile and sensitive discussion points of the subject. The technology extracts data from voice samples using more than 120 uncontrolled vocal parameters, and analyzes this using a set of algorithms to provide immediate and thorough results. It allows for faster truth verification, making the investigation process more efficient, and therefore, more cost effective for the organization. It has been found highly useful in the cases ranging from scams, terrorism, human trafficking, kidnapping, POCSO, homicide, extortions to arson, threats, intruders etc. The LVA system is a set of two different investigation focus tools as represented by LVA's different modes of operations. These modes are, Online Mode, which includes face to face interview with the suspect. The Offline Mode involves use of recorded CD. The Investigation Mode involves more of a focused interview

technique where the suspect has to answer in more direct form. LVA further features an additional recording service mode (“the quick recorder”). Presently, the LVA technology is used by many Directorates of Forensic Science and State Forensic Science Labs across the country. The administration of LVA does not require a court permission rather it can be executed by the permission of the State Police or the IO. However, the consent from the suspect is mandatory.



The new versions of LVA are LVA emotional diamond and LVA i.

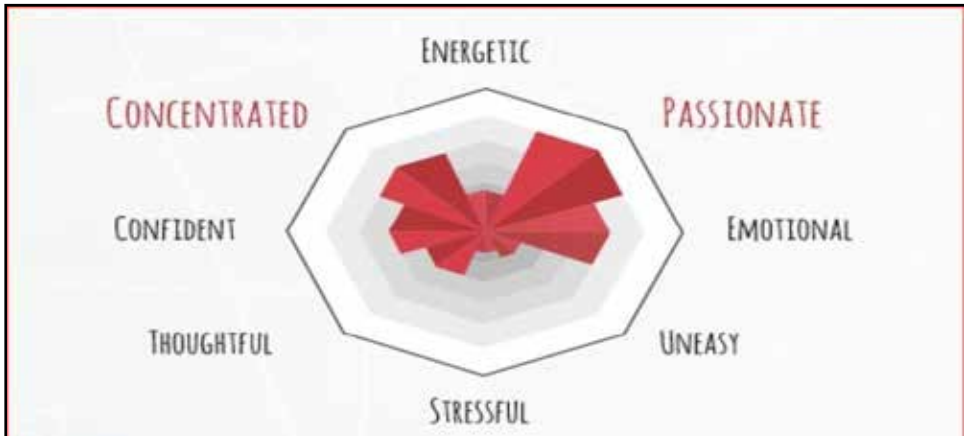
The “Emotional Diamond”

This concept was developed in 2012 to simplify the visualization and understanding of the human emotional reaction complexity as detected by the LVA. It is built of 8 wings: “Energy” at the top, “Stress” at the bottom, “Logic and confidence” to the left, “Emotion” to the right, and 4 additional indications displaying levels of “Passion”, “Uneasy”, “Mental Effort” and “Concentration”.

The core principle behind the Emotional Diamond is that there are no good or bad emotions, as they are all context dependent. For example, we would expect to see stressful reactions when discussing intimidating events, and we will look for energetic and emotional reactions when we discuss prospects and

achievements. When examining the emotional reactions over time, certain traits can be easily observed, and teach us about the true personality of the evaluated party.

Another version is LVA I which is used for research purposes.



Advantage

- The underlying principle behind the operation of LVA is that the human voice is viewed as behavior and it is the direct result of cortical activity.
- No sensor attached to the suspect.
- Non-invasive technique.
- Hon'ble court permission is not required for administering the test; however, examinee's consent is mandatory.

Specific to which crime

It is used as a screening tool where there are at a greater number of suspects and we need to filter from the pool of suspects. It has been used in cases of White-collar crimes, Murder, POCSO, Homicide, Criminal Attempt, Conspiracy, Theft crimes, Robbery, Forgery, Kidnapping, Sex Crimes.

Polygraph

Classic model

The earliest forms of Lie Detection techniques took on scientific aspects in the 20th century, with the development of techniques which incorporated measures of various physiological responses as the indicators of deception. The best known



of these techniques is “Polygraph”. It combines interrogation with physiological measurements such as respiration, heart rate, blood pressure and electrodermal responses. The first attempt dates back to 1985 when Cesare Lombroso made effort of detect deception on the basis of fluctuations in the blood pressure and pulse rates. Later in 1915, William Marston conducted many research and added blood pressure along with respiration readings to detect deception. The polygraph first came into significant contact with the legal system in 1923, when Marston attempted to have the results of a polygraph test admitted as evidence in the famous *Fyre vs. United States* in 1923 which was later was ruled against the admissibility of the results as evidence by the court of law. In 1926, Leonarde Keeler, known as the ‘father of modern polygraph’, improvised the polygraph instrument of Larson and added GSR as a third component. Modern polygraphs no longer use pens attached to tambours to write in ink onto a roll of paper driven clockwise in the way the original Keeler polygraph models used to work. It produces digital outputs that go directly from the measuring instruments into a computer with the appropriate polygraph software (Hirota et. al., 2005). The theoretical base for polygraph operation is governed by psychosomatic interaction principles which often results in defense mechanisms. A polygraph instrument records various physiological changes such as blood pressure, respiration, electrodermal responses and pulse rate simultaneously. These changes are involuntary function which are controlled by our autonomic nervous system.

The modern polygraphs consist of a Pelican Suitcase which holds the pneumatic and electrical sensors and a laptop which stores the readings and reports.

The pneumatic sensors consist of the

- i.) Pneumograph (Chest Assembly) which measures changes in respiration. It is the first sensor to be placed. One of them will be placed around the upper body area to record the thoracic breathing pattern. And the second is placed around the lower abdomen area to record the abdominal breathing pattern.
- ii.) Sphygmograph (blood pressure cuff assembly) which measures the blood pressure. It is fastened around the right arm over the brachial artery. In case of the pneumatic sensors the expansion and contraction of the muscles forms a pattern of wave. The transducer converts this wave into an electrical signal which is measured to arrive at conclusion.

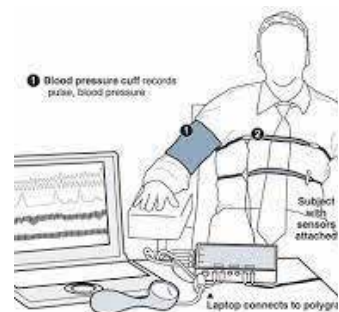
The electrical sensors consist of

- i.) Electro Dermal Activity (EDA fingerplate electrode assembly) which measures sweat conductivity. It consists of two stainless steel plates with Velcro straps and shielded cable for connecting it to the computer. The finger plates are attached to the index finger and ring finger tips of the non-dominant hand. It is measured in terms of skin conductance.
- ii.) Plethysmograph measures blood-pulse volume. Another sensor which is usually used is the Piezoelectric Sensor Pads or the P gauze (activity sensor) which is used as a counter measure to detect any form of physical movements.

The sensors are attached to the suspect and the test begins. The physiological changes form a pattern of wave. The respiratory activity is represented by the blue wave or line, the cardiovascular activity is represented by the red wave (line), the electrodermal activity is represented by the green wave (line) and the activity sensor is represented by the black



by the black wave (line). The transducer converts this wave into an electrical signal which are displayed as readings and measured to arrive at conclusion.



Paragon multisensory (6.50 version) is the newest version which consists of more no. of sensors.

Advantages

- Polygraph technique checks the veracity of the statement of suspect, witness, complainant.
- It replaces the third-degree methods of interrogation.
- It is ideal for white collar crimes

I. 1.5 Eye Detect

Overview

Polygraph examiners often conduct pre-test demonstrations in an attempt to



show participants that the polygraph instrument works. This is done to assist in reinforcing the test's validity, get the participant accustomed to the sensors, and to build trust in the process. These pre-test demonstrations are often called stimulation tests (STIM tests) or acquaintance tests. In the typical polygraph stim test, the examiner asks the participant to write down a number on a piece of paper between 3 and 8. At that point, the examiner asks the participant to divulge the number. Then, the examiner conducts a polygraph test asking the participant which number was selected. The participant is instructed to deny choosing the number written down. In other words, the participant is directed to lie about choosing the number. This is done to invoke a physical reaction when lying about the number chosen. During the polygraph test, the examiner attempts to demonstrate to the participant that there is a physiological change when lying about (denying) the number selected. The examiner shows the participant data from the polygraph instrument during the test to prove the participant reacted when asked about the number selected. The examiner is considered successful if she/he can show the participant that there was a physical change when lying about the number selected.

Number Test

Converus has created a similar test that is used as a demonstration of EyeDetect for customers and interested parties. This test is called the Number Test. Similar to the polygraph stim test, the participant is asked by the test administrator to choose a number between 2 and 9, write it down, conceal the number, and then take the EyeDetect test. The participant is also instructed to lie about the number chosen. However, in the case of EyeDetect, the Number Test is conducted "blind." This means that the participant does not divulge the number chosen to the test administrator until after the test is completed and scored. Conducting a stim test this way is considered riskier because the test administrator reveals the number to the participant prior to learning which number the participant selected. The EyeDetect Number Test has been conducted over a thousand times. The rate of accuracy is approximately 93%. The Number Test takes approximately 8 minutes. It's a simple, quick way to show that EyeDetect really works, without incriminating anyone in a real lie detection test. Instructions The number test is designed to show that it is possible to measure deception by observing subtle changes in the eyes, and those changes are involuntary and uncontrollable. Participants must fully cooperate while taking the test and follow the instructions.

The participant should remove any distractions from the testing area. The participant should use headphones to listen to the test instructions and questions. The test should be taken in a quiet setting, free of distractions. The test should be administered by a trained test administrator. The participant should choose a number between 2 and 9, write it down on paper, and put that paper in their pocket without disclosing the number to anyone. During the test, the participant must answer all questions truthfully, except when asked about the number chosen. When asked about the number chosen, the participant must lie and deny selecting that number. All questions are True/False. The participant must listen to the entire question before answering because the questions are written in a variety of ways (active voice, passive voice and with negations). This is done to avoid habituation. The participant must read and think about each question before responding (true or false). Under normal demonstration conditions, if the participant cooperates and responds accurately to the questions and if EyeDetect does not select the correct number, the participant will be given an economic incentive. If the participant does not cooperate, the system will detect it and will fail. The following are examples of non-cooperative behavior: o intentionally answering questions incorrectly (a high missed question percentage) o answering at random o not waiting until the entire phrase is read before answering o intentionally not answering the questions on time o squinting or blinking excessively.

How Does It Work?

The EyeDetect Number Test results are only based on measuring pupil dilation. Pupil dilation is one of the many eye behaviors monitored during a standard Test and it is very diagnostic. For the purposes of this test, pupil dilation is measured to show the diagnostic nature of that singular eye behavior. Questions The participant is asked to read statements, which are written in a variety of ways. See the table below for examples. To ensure the participant understands the instructions, the test administrator should review these question types with the participant prior to the test.

During the test, the test administrator should observe the participant to ensure they answer correctly. If there are excessive errors, the test administrator should stop the test, rehearse with the participant the true/false question format again, and re-start the test using the same number (which should remain concealed).



Geographical Profiling

Geographic profiling is the process of determining the most probable area of an offender's base of activities through an analysis of his or her crime locations (Rossmo, 2000). It is used most often in investigations of serial crimes or rape and also arson, bombing, robbery, terrorism and other crimes.

This technology assists law enforcement by focusing limited resources, resulting in the apprehension of the offender faster with less time spent and resources expended, and fewer victims. It's based on the connection between an offender's behavior and his or her non-criminal life. Both qualitative and quantitative methods are used to narrow down the probable locations.

It helps investigators to investigate cases from larger scale to reach to small amount of people. It helps investigators to know whether the crime was opportunistic and the degree of offender familiarity exists. Geographic profiling is growing in popularity and when combined with offender profiling, it can be a helpful tool in the investigation of serial crimes.

Geo-profiling (or geographic profiling) is a concept first proposed by Kim Rossmo in his doctoral thesis while at British Columbia's Simon Fraser University's School of Criminology in British Columbia, Canada in 1989. The crux of Rossmo's mathematics equation is a psychological theory called the least-effort principle. This concept proposes that criminals tend to commit acts of crimes within a comfort zone located near but not too close to their residence.

Key locations are weighted and then geocoded onto a map. The end process is known as a "jeopardy surface", a map that resembles a topographical map showing peaks and valleys color ramped to highlight the most likely area where that criminal resides.

Geographical profiling gained popularity among police agencies as a crime-fighting tool, having been put into practice within the FBI, ATF, Scotland Yard and other agencies of US, Canada, British and Europe.

It was originally designed for violent crime investigations.

CENTRAL CONCEPTS

Journey to crime –

The Journey to Crime routine is a distance-based method which makes estimates about the likely residential location of a serial offender. It is an application of

location theory, a framework for identifying optimal locations from a distribution of markets, supply characteristics, prices, and events.

The application of travel behavior theory to crime has a sizeable history as well.

The analysis of distance for journey to crime trips was applied in the 1930s by White (1932), who noted that property crime offenders generally traveled farther distances than offenders committing crimes against people, and by Lottier (1938), who analyzed the ratio of chain store burglaries to the number of chain stores by zone in Detroit. Turner (1969) analyzed delinquency behavior by a distance decay travel function showing how more crime trips tend to be close to the offender's home with the frequency dropping off with distance. The average distance traveled has evolved by that time into an analogy with the journey to work statistic.

Rational Choice theory

Rational choice theory is based on the fundamental tenets of classical criminology, which hold that people freely choose their behaviour and are motivated by the avoidance of pain and the pursuit of pleasure. Individuals evaluate their choice of actions in accordance with each option's ability to produce advantage, pleasure and happiness. Rational choice provides a micro perspective on why individual offenders decide to commit specific crimes; people choose to engage in crime because it can be rewarding, easy, satisfying and fun. The central premise of this theory is that people are rational beings whose behaviour can be controlled or modified by a fear of punishment.

This perspective assumes that crime is a personal choice, the result of individual decision-making processes. This means that individuals are responsible for their choices and thus individual offenders are subject to blame for their criminality. In terms of offending, rational choice posits that offenders weigh the potential benefits and consequences associated with committing an offence and then make a rational choice on the basis of this evaluation. Therefore, before committing a crime, the reasoning criminal weighs the chances of getting caught, the severity of the expected penalty and the value to be gained by committing the act. This means that if offenders perceive the costs to be too high, the act to be too risky, or the payoff to be too small, they will choose to not engage in the act.

Routine activity theory developed by Cohen & Felson (1979)

Routine activities theory is a subsidiary of rational choice theory. Developed by



Cohen and Felson (1979), routine activities theory requires three elements be present for a crime to occur:

- i.) a motivated offender with criminal intentions and the ability to act on these inclinations,
- ii.) a suitable victim or target, and
- iii.) the absence of a capable guardian who can prevent the crime from happening.

These three elements must converge in time and space for a crime to occur.

Felson and Cohen (1980) postulate that criminal activities are a “structurally significant phenomenon,” meaning that violations are neither random nor trivial events. In consequence, it is the routine of activities which people take part in over the course of their day and night lives that makes some individuals more susceptible to being viewed as suitable targets by a rationally calculating offender. Routine activities theory relates the pattern of offending to the everyday patterns of social interaction. Crime is therefore normal and is dependent on available opportunities to offend. If there is an unprotected target and there are sufficient rewards, a motivated offender will commit a crime.

Crime Pattern theory

Paul Brantingham and Patricia Brantingham (1981, 1984) in their model of offense site selection, known as the Crime Pattern Theory, suggest that crimes are most likely to occur in locations where the activity space of a victim or target intersects with the awareness space of the offender. The theory supports that most offenders choose their crime sites not randomly, but after having considered many parameters. Although victims can be selected when the circumstances allow it, or by any chance, the process of the selection is based on a structure defined by 7 space whether it is realized by the perpetrator or not. This spatial selection process is compatible with Routine Activity Theory focusing on how relevant the regular and routine victim behaviors is to understand crime patterns (Clarke & Felson, 1993).

Choosing a target is affected by the offenders’ interactions with their physical and social environments (Brantingham & Brantingham, 1993). The main premise of the theory is that offenders like everybody else, take information for their environment during their normal legitimate everyday activities. Brantinghams describe it as “activity nodes” which corresponds to a place when someone

stops and performs activities s/he would do in everyday life. To regular people, an activity node includes home, workplace, a shopping area, places for leisure time or the homes of friends and family. On the other hand, “Paths” can describe the routes an individual take from one node to another. Together, “Nodes and Paths” comprise an individual’s “activity space”.

Important factors of Geographical profiling

1. Crime Locations

A crime will contain evidence. The evidence found at the location provides information leading to the offender and victim’s prior location, clues as to where they may have gone, as well as information depicting what happened. Collecting and comparing clues from numerous crime locations influences the development of the offender’s patterns.

2. Offender type

According to Dr. Kim Rossmo there are four different types of offenders with regard to geographic profiling. Hunter: the hunter singles out a specific victim without leaving his home territory. He will commit crimes where he lives. Poacher: a poacher will travel out of his home territory to do his hunting. Troller: A troller will realize an opportunistic encounter while occupied in other activities and then strike. Trapper: a trapper will draw the victim into him using different seemingly harmless situations.

3. Hunting methods

Hunting process can be broken down into two parts. (1) The search for a suitable victim, and (2) the method of attack.

4. Target Backcloth: the spatial opportunity structure of crime sites

“Target or victim backcloth is important for an understanding of the geometric arrangement of crime sites; it is the equivalent of the spatial opportunity structure (Brantingham & Brantingham, 1993b). It is configured by both geographic and temporal distribution of “suitable” (as seen from the offenders perspective) crime targets or victims across the physical landscape. The availability of particular targets may vary significantly according to neighborhood, area, or even city, and is influenced by time, day of week, and season; hence, the term structural backcloth is also used.”



5. Arterial roads and highways

Large Roads and highways play a huge part in crime strictly because it how both criminals and victims are forced to travel. Crimes will often cluster around freeway exits and entrances.

6. Bus stop and train stations

These are two forms of rapid transportation that may also be used by offenders and victims and can be hot spots in certain areas.

7. Physical and psychological boundaries

Offender and victim alike are both restrained by physical boundaries such as rivers, lakes, oceans or highways. Psychological boundaries may also affect movement, for example a black offender may not travel into a white neighborhood for fear or being identified.

8. Extent of land use

Assessing how far a person would have used to reach the target or probable target using the transportation facilities available.

9. Neighborhood demographics

Certain offenders prefer a certain ethnicity of victim, if so then he may hunt in different neighborhoods affecting spatial crime patterns.

10. Routine activities of victims

Understanding the routine of a victim may provide insight into how the offender searches for his victims.

11. Singularities: single incidents that do not appear to fit the whole picture.

12. Displacement (includes social location and physical movement of the victims).

Geographic Profiling Analysis (GPA) training

It is a theoretical training which lasts for about 1 week.

The training includes either making a demo crime scene or take the standard crime information into consideration and the participants are asked to put the theories into practical and thereby solving the current case.

Mostly used in foreign countries for training.

Limitations

- It only considers the spatial behavior of serial offenders.
- It may not distinguish between multiple offenders operating in the same area and following similar mod. operandi.
- Although computer systems can be highly sophisticated, they cannot analyze all the information involved in a crime series and they are only as good as the accuracy of their algorithms' underlying assumptions and we cannot rely on computer to narrow down the geographical sites.

Forensic Statement Analysis

A forensic psychological opinion in statement credibility has high validity only when the interview corresponds to a very strict scientific standard, and when the evaluation is done competently. There are two types of techniques-

1. Criterion Based Statement Analysis (CBSA)

The principle behind this is the production of a lie requires more cognitive energy than the production of a truthful account. It has 19 criteria based on which the statements are analyzed. They are-

- a) Logical Structure
- b) Unstructured production
- c) Quantity of Details
- d) Contextual Embedding
- e) Descriptions of Interactions
- f) Reproduction of conversation
- g) Unexpected complications during the incident
- h) Unusual Details
- i) Superfluous details
- j) Accurately reported details misunderstood
- k) Related external associations
- l) Accounts of subjective mental state
- m) Attribution of perpetrator's mental state
- n) Spontaneous details



- o) Admitting lack of memory
- p) Raising doubts about one's own testimony
- q) Related external associations
- r) Self-accusation
- s) Pardoning the perpetrator

2. Scientific Content Analysis (SCAN)

It was the brain child of Avinoam Sapir. It involves obtaining a pure statement and analyzing the quality of the structure and content of that statement. The flow of the truthful statement and the credibility by pronouns are checked.

Forensic Audio Statement Analysis

Graphology

Graphology or the handwriting analysis is the field of identifying and understanding the behaviour, personality and characteristics of an individual by analysing the handwriting of a person. The graphology as a science is not new to the world it is being in used from the past 400 years. Camillo Baldi is considered as the father of graphology by giving the systematic observation of handwriting in the year 1622. The term “graphology” was coined by Abb Jean-Hippolyte Michon in Paris in 1897 by the combination of two Greek words ‘graphein’ which means ‘to write’ and logos which means ‘science’ (Deshpande, 2016).

Handwriting is not handwriting it is basically the brain writing as with the response from the brain the person is able to write. A unique pattern is produced by the brain which is as similar with every individual that reveal the personality trait. It is also able to give the brief knowledge about person's intellect, his emotions, fears, aptitude level, skill, their motivation and integrity (Kedar et al, 2015).

The forgery in any other person's handwriting can be analysed and identified by proper examination of the characteristics like pen pressure, spacing, formation of letters etc. (Dang and Kumar, 2014).

Graphology is useful in understanding personality traits through the strokes and patterns revealed by individual's handwriting which itself signifies the traits such as emotional and mental instability.

Graphology in forensic study

Hence these traits are important to be known and can be helpful in dealing with the cases of profiling of any serial killer or any criminal and suspect so as to narrow down the search of an investigation. The graphological studies plays a very important role in the forensic science for dealing with the cases related with psychiatric activity of any criminal or the cases related with any suicide notes, anonymous letter etc. Graphology in forensic is the study of handwriting especially that found in ransom notes, poison pen letters or blackmail demands. The identification of a criminal on the basis of its personality which are also helpful in finding the modus operandi of any serial killer or an insane criminals.

Research Studies

Gluhchev (2007) suggested the importance of handwriting analysis in the field of forensic investigation. Image enhancement technique are helpful in improving the quality of image of any handwriting sample which are found in a bad quality and the image segmentation method is helpful in segmenting the image by eliminating the background and the separation of the rows and separation of words.

Cronje and Roets (2013) carried the graphological studies as the purpose of clinical or diagnostic method. With the fact that handwriting is a unique feature as that of fingerprint, hence in his conclusive part they reveal that the person handwriting seems consistent during the entire time period of his life expect some of the intra variation occur in the handwriting.

Djamal et al. (2013) used the graphology as for the purpose for revealing the overall picture personality of a person for the selection of the employees. Hence here the research work is proposed for the recognition of handwriting with the involvement of identification of style of signature and digit of character using the network that can predict the personality of an individual. The outcome of the research work is done with the help of the Artificial Neural Networks.

Singh et al. (2016) discussed the case report about a patient of MBBS student who is having a complaint in the change in her handwriting from past long time. Hence the graphological studies is helpful in identifying the reason behind it. Also after the detailed interview with the patient it came to the conclusion that the patient is suffering from the depression of conflict with her 5 year relationship bond. Hence on the basis of viewing different writing sample of her either it's a letter sent to his brother whom she is emotionally attached or letter

to her teacher whom she had no emotional attachment reveals the mind-set of a patient. The patient condition were discussed on the basis of the presentation of her high depressive condition revealing the initial complain of her handwriting change. Hence the change in the handwriting converted into the psychiatric symptom of a person.

On the basis of the paper of Singh et.al. (2016), the handwriting analysis used a tool for the understanding of an emotional state of a person which can further Incriminate during his/her Psychiatric judgement. Though It is helpful in revealing the psychiatric condition of a person, so it will surly plays a very significant role while dealing with the cases related with any suicide or criminal insane activity. As with the known fact that the handwriting is a neuromuscular activity the handwriting itself became a very reliable tool for investigating the cases in the forensic world where profiling of a criminals mind, modus operandi of attempting the crime plays a positive role.

Methodology

Basically, there are two ways to carry out the handwriting analysis with the intend to determine personality traits through it and these are:

- I. Manual way
- II. Automatic handwriting analysis through computer

Manual analysis relies on the knowledge and observation of the graphologist. After the handwriting sample is obtained, the graphologist looks for the various handwriting features and tries to identify them to analyze the writer's personality, few of the important features are as follows:

- a. Word Spacing
- b. Line Spacing
- c. Page Margins
- d. Alignment
- e. Pen Pressure
- f. Slant
- g. Size and Position of Letters
- h. Movement
- i. Headings

- j. Tendencies towards right or left
 - k. Observing the Position as well as Shape of i-dots
 - l. Observing the Position as well as Shape of T-bars
- Computer aided graphology (CAG) system. It is one of the system which enables the graphologist to take advantage of computer in order to achieve faster and error free analysis of handwriting and to obtain the personality description of the writers on the basis of the analysis. The CAG system involves the following steps:
- Scanning, Pre-processing of the image, feature extraction, analyzing features.

Analysis

a) Word spacing

It is indicated by observing the width of one letter in handwriting.

It is the easiest way to judge a person by looking at narrow or wide space between the words.

- i. If there is wide space found between the words then the writer usually avoids the crowd and is comfortable in spending some alone time.
- ii. If there is narrow space found between the words then the writer may be intrusive and usually found to be enjoying in the crowd.

b) Line spacing

Line spacing can be better observed if the handwriting samples are taken on a blank (or unlined) sheet of paper. It has been found that:

- i. Those who have wide spaced lines in their handwriting are usually open-minded persons and have an attitude to take a stand back.
- ii. Those who have narrow spaced lines in their handwriting are usually narrow-minded persons and are used to react when close to the action.

c) Page margins

The margins should not be neglected while analyzing a handwriting since they can provide a lot of information, such as:

- i. The left margin indicates towards the roots or family.
- ii. The right margin indicates towards the other people in a person's life as well as future.
- iii. The top of the page indicates towards the goals and ambitions.



- iv. The foot of the page indicates towards the energy, practical approach as well as instincts of a person.
- v. A wide left margin in handwriting indicates that the writer likes moving on, however a narrow one indicates towards the cautious behavior and to avoid being pushed before the person is ready to do a task. A wide right margin in handwriting indicates that the writer has a fear of the unknown, however a narrow one indicates towards the eagerness and impatience to do the things.

d) Alignment

The alignment of handwriting can be better judged when the writing samples are taken on a blank sheet of paper. The alignment can be analyzed by checking the handwritings against an imaginary baseline usually three cases are found:

- i. Upward alignment

In this case the handwriting is found to be in the upward direction as compared to that of the imaginary baseline. It usually indicates that the writer is optimistic; also it could be found if the person is excited or happy while writing.

- ii. Downward alignment

In this case the handwriting is found to be in the downward direction as compared to that of the imaginary baseline. It usually indicates that the writer is pessimistic; also it could be found if the person was emotional or upset while writing.

- iii. Straight alignment

In this case the writing is found to be straight and somewhat parallel to the imaginary baseline. It usually indicates that the writer likes discipline or is an organized person.

e) Pen pressure

Some people write with heavy pressure and those are usually found to be slow writers. It has been seen in many cases that illiterates write with heavy pressure. Also, the persons who are very emotional are tending to write with heavy pressure.

- i. Mostly people write with moderate pressure having fewer indentations.

The persons who write in this way are tend to be balanced emotionally.

- ii. Some people are used to write very lightly with smooth and uniform thickness

and rhythmic writing. They are used to have empathy to people and are sensitive.

- iii. However uneven pressure indicates lack of vitality.

f) Slant

Slant refers to the angle of inclination of handwriting or a letter of it from that of the baseline, following cases can be observed:

- i. The slant could be forward if the words or sentences are leaning towards the right.
- ii. The slant could be backward if the words or sentences are leaning towards the left.
- iii. The slant could be vertical also and if more than any two above categories then it could be inconsistent.

g) Size and proportion of letters

It is a habit in which combination and comparative size of block and small letters are taken into considerations. Size and proportion can be estimated by comparing the sizes of the letter specially the middle case letters with the capitals thus comprising of three zones which could be attributed as, Upper, Middle, Lower. A usual criterion is to judge the size by attributing 3 mm per zone and thus sets a measure of 9mm for full height; the size more than this will be large whereas that less than this is small.

- i. Large size handwriting: It indicates towards the extravert as well as confident behavior of the person.
- ii. Small size handwriting: It indicates towards the introvert as well as academic behavior of the person. If the handwriting is small and known (or are similar in one way or the other) to him/her.

h) Position and Shape of i-dots

- i. If an 'I' is written without any dot then it indicates toward the absentmindedness of the writer.
- ii. If the dot on the letter 'I' is placed high above then it indicates that the writer is imaginative.
- iii. If the dot on the letter 'I' is formed like a circle then it indicates towards the artistic personality of the writer.
- iv. However, an open dot may also indicate towards the affection and a visionary.



i) Position and Shape of T-bars

- i. There are various ways in which the stem as well as the cross bar can be written and hence the letter 't' is very revealing in terms of graphology.
- ii. If the letter 't' looks like a star then it is a sign that the person has the strong sense of responsibility.
- iii. If the cross bar is slanted in the upwards direction, then it is a sign that the writer is ambitious.
- iv. If the cross bar is high and rises away from stem in the right-side direction then it indicates leadership qualities and intelligence.

Narco-Analysis

It is considered to be a scientific, precise and humane approach to detect crime which gained popularity around 1940s as an alternate to third degree treatment. It is quite popular in India where the results are used as corroborative evidence in the process of crime investigation. A court mandate is a compulsory requirement for its execution under any DFS. It is a form of psychotherapy which acts as an effective aid to scientific interrogation. It is also known as truth serum or drug hypnosis. It can be defined as a psychotherapy that is conducted while the patient is in sleep like state induced with the help of psychotropic drugs like Sodium Pentothal, as a means of releasing repressed thoughts, feelings or memories. It roots back to the prepsychoanalysis days where Freud used hypnosis to relax patients to help them discuss/disclose emotionally difficult matters. He used hypnosis to get over the mind's natural resistance and access the unconscious. Narco Analysis is a process of "abreaction" or catharsis. It is an invasive technique. The underlying principle is that when we lie, our thoughts are filtered by the brain on what to be withheld and what to be disclosed. These drugs work on the principle of inhibiting the thought filtration procedure of the brain following which the person can no longer shift his/her idea and so speak the truth.

Advantages

- It is believed that under the influence of drugs, if a person's way of thinking can be restrained without affecting his/her memory, s/he can speak freely without any manipulations
- To extract crime related concealed information from the subject.
- It also acts as an effective tool to eliminate innocent person.

Provision for Improving Rehabilitation Facilities in Prison Set Up

Implementing the use of Neurofeedback and Counselling Neurofeedback therapy is a noninvasive procedure that measures a patient's brainwaves and provides the patient with real-time feedback about how the brain is functioning. It's a type of biofeedback, which is a mind-body technique that aims to help patients gain voluntary control over certain body functions that are typically involuntary (such as heart rate, muscle contraction or brainwaves). Neurofeedback therapy, in particular, is used to help teach self-control of brain functions by indicating to patients how their brains react to certain triggers. Over time, patients learn to recognize when their brain is in a certain state. Then, they can learn to recreate the desired state, such as relaxation, or avoid undesired states, such as agitation, in their daily lives.

Requirements & Recommendations

Appointment of Forensic Psychologist

There should be more appointments for the post of forensic psychologists and their roles must be clearly defined.

Forensic Act

An act must be developed which would work as a legal framework defining the nature of work, roles and responsibilities for all forensic psychologists.

Research

A committee should be developed to conduct continuous researches on various aspects of forensics and how it can be applied in various situations. Meta-analysis must be done to understand the current trend, the existing limitations and work on how the situation can be improved and strengthened.

Chapter 6

Toxicology

Dr. Madhulika Sharma¹ and Dr. Adarsh Kumar²

Situation Analysis

The Forensic Science Laboratories are not able to manage timely disposal of cases pertaining to the analysis, for detection of poison(s) in the viscera, for ascertaining the cause of death in homicidal, suicidal or accidental deaths, which impedes expeditious dispensation of criminal justice. The backlog of such cases is mounting in most of the FSLs in the country. The NHRC Core Group had an in-depth study of this complex, deep-rooted and multidimensional problem. What obstructs these laboratories to manage timely disposal of viscera cases, merits immediate attention at the Government level.

Application of Primitive Autopsy Procedures in Hospitals

Currently, the autopsy surgeons are following sampling procedures prescribed in the 'Manuals' of the Police, and Medical departments of the concerned States. Interestingly, these manuals are primarily based upon the scientific techniques developed during the beginning of the 19th Century (Mathieu Orfila: 1787-1853). According to these manuals, a viscera sample usually comprises the following items:-

- i. Stomach with its contents,
- ii. Liver – half or whole,
- iii. Small intestine, about one foot piece,
- iv. Half of each of the two kidneys,
- v. Spleen,
- vi. Lung, in cases of volatile poisons,

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- vii. Heart, in case of cardiac poisons,
- viii. Brain in cases of cerebral poisons,
- ix. Spinal cord in case of spinal poisons,
- x. Bone, hair, nails – in case of metal poisoning,
- xi. Uterus and vagina, in cases of abortifacient drugging,
- xii. Skin – subcutaneous tissue and muscle, from the site of injection/bite,
- xiii. A sample of blood.

The present autopsy procedures followed in India are out dated. These procedures were devised to suit the chemical procedures, and the post-mortem equipment available about a century ago. Large quantity of various organs of a cadaver was pre-requisite for the then available analytical techniques. Compounding the body tissues eliminated the risk of any poison passing undetected during the analysis.

During discussions, medical officers expressed apprehensions that in certain poisoning cases, physical signs may not appear in the dead body. Moreover, a number of new drugs (poisons) were available in the market, about which they lacked sufficient information. The autopsy surgeon expresses his helplessness in assigning the cause of death on the plea that the police officer handling the case does not provide him with sufficient information about the case. He, therefore, is constrained to refer viscera in such cases to the FSL to rule out poisoning as the cause of death. Autopsy surgeons feel that if the investigating officers provide them with adequate background of the case, rate of reference for chemical analysis of the viscera is bound to be reduced. The investigating officer, on the other hand, is hard pressed, as the time (period between occurrence of the incident and autopsy of the dead body) is too short to gather enough information and evidence for medical doctors to be convinced.

Application of Primitive Analytical Procedures in FSLs

The Forensic Science Laboratories, already understaffed and starved of resources in the form of state-of-the-art equipment and modern infrastructure facilities, are not motivated to reform the primitive and time consuming analytical techniques. These laboratories generally carry out chemical analysis of viscera on 'first-come first-served' basis. Each organ, comprising the viscera, is manually cut into pieces before it is processed for extraction and isolation of poisons by distillation, wet digestion, ashing, de-proteinisation, solvent extraction, filtration



and drying. The entire exercise for processing a large quantity of viscera for extraction and isolation of toxic substances is hazardous and time consuming. After separation follows the chemical analysis for detection and identification of poison(s). In the absence of validated test-procedures for viscera analysis, the analytical methodologies and their sensitivities vary from laboratory to laboratory. At present, complete toxicological analysis of a viscera sample by traditional Forensic methods normally requires about a week's time, due to which the Forensic Science Laboratories are unable to manage the work load inspite of their optimum performance in this field. The Core Group observed that most of the FSLs are out-performing the BPR&D work-norms established for viscera analysis in the country. Under pressure of work, 'practice' usually outruns the 'theory', which may result in compromised quality of the output. Forensic Science institutions in advanced countries have discontinued the old analytical procedures long back and are able to furnish the scientific opinion within 48 hours now. Their autopsy protocols commensurate with sophisticated and modern micro-analytical techniques available at present.

Delay in the Submission of Viscera to FSL

The time taken by the investigating agencies to deliver the viscera at the FSL is also a matter of concern. The delivery time varies from a few days to a year after the autopsy. A survey of the time taken in handing over the viscera to FSL reveals the following statistics:-

Number of cases delivered within 1 month	=	35%
Number of cases delivered within 2 months	=	25%
Number of cases delivered within 3 months	=	15%
Number of cases delivered within 6 months	=	16%
Number of cases delivered within 6 to 12 months	=	08%
Number of cases delivered within 1 year	=	01%

The delay in the analysis of viscera also has adverse effect on the quality of results. The methods followed in India are primarily devised for residual poisonous matter available in the viscera. Volatile poisons may be lost with time. In case of marginal lethal ingestion of poison, residue of the toxic substance may not be left for detection in the viscera. The old traditional methods fail to yield satisfactory results under such boundary conditions. Most of the laboratories do

not have proper infrastructure facilities for preserving the unexamined viscera samples. There are poisonous substances, which undergo chemical changes due to putrefaction of viscera and are broken down into their metabolites. Besides diluting the evidence, the putrefaction of viscera under hostile climatic conditions pollutes the laboratory environment. The gases released from the degraded viscera are hazardous and disagreeable, which seriously impedes the efficiency of the Forensic scientists handling the viscera, Infact, delayed viscera examination not only affects the quality of result but also poses a great a risk to the health of the scientists handling it.

Possible Solutions for Reducing Pendency

Actions by the Police Investigating Officer

Unnatural deaths, homicidal, suicidal, accidental or other wise are investigated by the Police to determine the cause of death. Majority of the cases pertains to 174 Cr. P. C., 176 Cr. P.C., 302 IPC, 306 IPC and 498 IPC. The investigating officer must collect the circumstantial details, eyewitness accounts and the possible physical clues to confirm the crime and its modus operandi. In all those cases, where poison is suspected to have been used, the medical doctor should be advised to collect and preserve the viscera for Forensic Science Laboratory analysis. The investigating officer may request for preservation of viscera for Forensic Science Laboratory analysis where the 'Inquest Panchnama' or the 'Scene of Crime Panchnama' indicates that the deceased had consumed liquor or poisonous substance or he was under the influence of narcotics or sedatives. In any case, if chemical analysis of the viscera is required for ascertaining the cause of death, the autopsy surgeon should properly preserve the viscera sample. The viscera samples so preserved should be delivered at the FSL without unnecessary loss of time.

Actions by the Autopsy Surgeon

A study of the cases forwarded to FSLs for toxicological analysis revealed that in 30 to 40 percent of the cases, Forensic Laboratory examination of viscera is avoidable. These include cases of drowning, burning, strangulation, road accidents and trauma deaths. Indiscriminate references unnecessarily add to the workload of the Forensic Science Laboratories. Autopsy of the dead body should be conducted by a qualified and experienced autopsy surgeon to identify the cause of death. If the doctor is able to establish the cause of death, other than poisoning, the viscera need not be referred to the FSL for analysis.



Poisoning is usually manifested through internal and external symptoms on the cadaver. If the circumstantial details indicate that poison was consumed by the victim, and the autopsy observations also support the contention, viscera may be preserved and sent to the nearest FSL, for chemical analysis to identify the poison qualitatively and quantitatively. In those cases, where the cause of the death is not established during the police investigation and/or physical signs and symptoms of poisoning are not clear, viscera may be referred to FSL for in-depth scientific investigation and opinion.

Viscera Sampling Procedures, Preservation and FSL Reference

Selection and preservation of viscera or body fluids has a direct bearing on the quality of results of the laboratory analysis. There are instances where indiscriminate use of the preservative has interfered and affected the analysis. The choice of preservative would depend upon the nature of the poison consumed by the victim. Preservatives, which may mask the poisons or their metabolites or affects the scientific analysis, should be avoided. In fatal cases of poisoning, the following scheme of preservation is recommended:-

- i. Blood sample, approximately 10 ml, should be preserved in about 10 mg Sodium Fluoride and 30 mg of Potassium Oxalate per 100 ml of blood.
- ii. In carbon monoxide poisoning, 2-3 mm thick layer of liquid paraffin over the blood sample may be used.
- iii. Liver, approx. 25 gm should be preserved in saturated solution of commonsalt.
- iv. In cases of mineral acid poisoning, liver sample should be preserved in rectified spirit.
- v. Urine sample should be preserved by adding 2-3 ml HCL per 250-500 ml of urine.
- vi. The preservative used for the samples should be indicated in the forwarding letter and small quantity of the preservative must also be sent along with the samples to FSL.
- vii. In non-fatal cases, samples of vomit, stomach wash, urine and blood may be forwarded for examination.

Measures by the FSLs to Reduce Pendency

With the advancement in science & technology, Forensic Toxicology at international level has recorded phenomenal progress during the last decade.

Application of latest analytical techniques such as Chromatography-Mass Spectrometry have enhanced the accuracy, precision and speed of the laboratory analysis, without requiring bulky visceral samples. A number of quick and more accurate methods for extraction of poisons or their metabolites have now been developed and are available for laboratory use. Solid-phase Micro-extraction technique is the latest development. A specially coated fiber tip can directly absorb organic compounds from the tissue, and can straightway be tested and thus save processing time. Accelerated Solvent-extraction and Micro-diffusion techniques for rapid separation and analyses are also used in many advanced countries. The micro-analytical techniques have the advantage of eliminating the interference due to co-extractable substances, which may otherwise mask the traces of poisons or their by-products present in the viscera. Besides the above, manual handling of putrefied and infected viscera, in the laboratory, is also minimized. By the application of these new techniques, the efficiency and analytical capabilities of Forensic toxicologists can be enhanced manifold.

The variety of poisons which are commonly encountered during analytical probing may be classified into gaseous and volatile substances, Metallic poisons, Organic and Vegetable poisons, Acids, Toxic anions, Pesticides, Barbiturates, Benzodiazepines, Amphetamines, opiates etc. Optimum standards will have to be defined to ensure uniform, quick and reliable Forensic opinion. The old test procedures viz. colour tests, crystal tests, physiological tests may be replaced by two tier (Screening and Confirmatory) analytical procedure for quick and accurate test results. Spot tests for screening may be excluded from the parameters for identification of toxic substances. Any three pertinent and independent techniques, out of the following, are recommended for identification of drugs and poisons in viscera.

- i. Gas Chromatography – Mass Spectrometry;
- ii. Fourier Transform Infrared Spectrometry;
- iii. FT-Raman Spectrometry;
- iv. Thin Layer/High Performance Thin Layer Chromatography;
- v. UV- Visible Spectrometry;
- vi. Gas Liquid Chromatography;
- vii. High Performance Liquid Chromatography;



- viii. Radio Immunoassay;
- ix. Radio Immunoassay;
- x. Inductively Coupled Plasma – Atomic Emission Spectrometry.

It is recommended that the facilities for these techniques be created at every State/Central FSL to solve the problem of delay in handling toxicological analysis of viscera.

Since the inception of scientific support in the crime investigation, the medico-legal work component, such as post-mortem, determination of the cause of death, body injuries etc., have been entrusted to the departments of Forensic Medicine in the Medical Colleges or Civil Hospitals. The chemical analysis of blood, viscera or stomach wash, etc. is being undertaken in the Forensic Science Laboratories or Chemical Examiner's Laboratories. These activities at two different places, under two different incompatible commands, results in inordinate delay in scientific opinions. Sometimes, inconsistency between the opinions of the forensic scientists and post-mortem practitioners leads to confusion during expert testimony in the courts of law and the benefit of doubt leads to acquittal for the criminals. Putting these functions together within the ambit of Forensic Science Laboratories can control such a situation. This will require creation of posts of medico-legal visor in every Central/State FSL of the country.

Chapter 7

Wildlife Forensics: Understanding Dynamics of International Wildlife Trade and Mitigating Wildlife Crimes

Dr. Malay A. Shukla¹ and Dr. Satish Kumar²

1. Introduction and Review of the topic

India is amongst the 17 mega-biodiversity countries of the world, encompassing around 7-8% of the recorded species of the world. Another striking feature of India's biodiversity can be assessed by the presence of 4 biodiversity hotspots amongst 34 hotspots recognized globally (Mittermeier et al., 2011). India is also a vast repository of traditional knowledge associated with biological resources. Biodiversity conservation is important for sustainable development of local people depending on forests and animals for their survival. Wild species in South-Asia and especially India are facing serious threat from habitat fragmentation, habitat loss and degradation; over-exploitation of natural resources; loss of genetic diversity; effects of climate change and desertification; and most importantly poaching (Isaac et al., 2007; Challender et al. 2015)

Wild animals in India are given the protection status under various schedules (I-IV) of Wildlife (Protection) Act, 1972 of India (WPA). Illegal and illicit trade of wildlife parts and products is amongst fourth largest illegal crime after firearms, drugs and human trafficking. As per the report published by Interpol, during 2020, wildlife crime is escalating at the rate of 5% to 7% annually which is almost double the growth rate of the global economy (Interpol, 2020; <https://www.interpol.int/en/News-and-Events/News/2020/Wildlife-crime-closing-ranks-on-serious-crime-in-the-illegal-animal-trade>). Committing wildlife crime has always been a lucrative market with organized syndicates working globally

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with least risk and high purchase value. Since last two decades' illegal trade of wildlife parts has taken a toll of many endangered and valuable species including tiger, leopard, snow leopard, bear species, deer species, pangolins etc. Illegal wildlife trade is rampant across all the states of India chiefly because of porous borders and inefficient enforcement. Wildlife in India is more prone to poaching pressure mostly because of demand of their parts and products in international market for traditional medicines preparations as well as local consumptions and as trophy material. There has been exponential growth in wildlife crimes over few decades.

Wildlife Forensics has always been a low priority area for government and enforcement agencies. However, isolated efforts have been made by various organizations to deal with wildlife crimes and neutralize the demand of wildlife parts and products. Superficially simple looking wildlife crime is actually a complex phenomenon and tactfully executed act that involves group of people at national and international level to fulfill the demand of wildlife products to end users. It is inevitable to adopt multi-faceted approach, full use of available resources in forensic science, inter-institutional cooperation and human resources to effectively enforce the Wildlife (Protection) Act, 1972 of India and ultimately help in enforcement of CITES treaties.

Many species in India are already extinct due to over poaching and many have been under endangered category. Still, few are being pushed through the gruesome process of poaching as a substitute to tigers and rhinos. Although there has been a considerable time lapse in keeping a check over quantum of wildlife trade, it is an urgent need of hour to take stringent measures to have a better enforcement system in wildlife crime cases. Since its inception during 1990's, Wildlife forensics has always been a neglected field and needs human resources, funding and equal weightage as in human forensics. Wildlife forensics is mainly concerned with identification of species from confiscated wildlife parts or products as well as identification of person(s) involved in committing an offence. Though, possession of wildlife article itself is an offence as per Wildlife (Protection) Act, 1972 of India, it is necessary to link the suspect with origin of crime and the end user so as to forfeit any further possibilities of escaping from legal proceedings.

Official statistics are not the actual measures of the extent of crime that has been deep-rooted in the modern Indian society, the reason being the under-reported of crimes in India (Rao, et. al., 2016). As per the report published in NCRB

Journal (Malaviya, 2019), on an average Rs. 10,000 is spent/trail in India by various law enforcement agencies. Further with a acquittals in major criminal cases like murder, rape cases, etc., lot of money gets wasted and ultimately boosting criminals confidence and degrading citizens faith in justice delivery system. Hence in order to understand the complex network nature of wildlife crime, it is necessary to implement multi-faceted wildlife crime investigation (Challender et al., 2015; Symes et al., 2017).

2. Current Landscape of Wildlife Forensics in India

Over the years, various organizations have been actively involved in mitigating wildlife crime according to their expertise and in various capacities. Various enforcement agencies viz. forest department, Wildlife Institute of India, Wildlife Crime Control Bureau, Department of Customs, Department of revenue intelligence, police department, etc. have been playing their part to investigate wildlife offence cases. Amongst the few, Wildlife Forensic Cell, Wildlife Institute of India (WII) based in Dehradun is considered as nodal agency in mitigating wildlife crimes through extensive research and case analysis from different states of India and accomplished major task of establishing various protocols for analysis of Wildlife parts and products of major species in India based on Morphometry and DNA based techniques. Since last decade, Wildlife Crime Control Bureau (WCCB) has been stupendous in controlling wildlife crimes in India through their extensive intelligence networking. All these institutes have played their part to keep check over wildlife trade but somehow lack of proper coordination and a common link amongst them has played a spoil sports in effective enforcement of Wildlife laws in India.

Global wildlife trade is going unabated, however, there is no quantified data at global level to scale the extent of illegal and legal wildlife trade and if available, the data varies in magnitude and values. (Smith et al., 2006). The data estimated till data have been either obtained from predatory sources, unreliable media like under-rated journals, publications or newly established NGO`s. ultimately raising credibility of data on quantum of wildlife trade. There is a surgent need to quantify data on illegal wildlife trade at national and international level, that will help in identifying road map for further policy making and taking informed decision through robust Act and amendments as passed by parliament of India.

While we try to quantify illegal wildlife trade, it is necessary to understand the complex nature of questions and seek potential solutions in this area:



- How will the illegal wildlife trade affect the biological ecosystem?
- Which are the driving forces that lures traffickers in International wildlife trade?
- What are the policy decisions taken so far and how to mitigate ever increasing wildlife trade though understanding of pattern and flow of wildlife trade; and accordingly intervening in designing framework for effective enforcement of wildlife and subsidiary umbrella legislations?

One of the major problems in the existing wildlife crime scenario in India is the lack of centralized and State-of-the-Art facility to deal wildlife offence cases. Despite of advanced Morphometry and DNA based techniques; it is difficult to prove the integrity of case because of various reasons. Some of the factors/reasons that can be attributed are: lack of human interface as an evidence; improper documentation; lack of Standardized protocols for species identification; lack of centralized reference sample repository and lack of awareness amongst enforcement agencies to deal wildlife offence cases. All these institutes have played their part to keep check over wildlife trade but somehow lack of proper coordination and a common link amongst them has played a spoil sport in effective enforcement of Wildlife laws in India.

Importance of human interface in Investigation of wildlife crime cases

Till date majority of cases analyzed are more centered towards species in question whereas human related parameter like fingerprint at crime scene, digital evidences like cell phone location and details; forensic psychological profiling of suspects; ballistics evidence, etc. Incorporating the use of already existing State-of-Art facility of human forensics at National Forensic Sciences University (NFSU) will help in strengthening the cases and nail down the criminals involved in organized syndicates.

Investigation of crime scene is an important aspect for better law enforcement and maintaining law and order in any country. With the advent in modern tools and techniques it is now a demand of time to deal cases in scientific manner. Most of the Wildlife Forensic Facilities established across the World are a separate unit and deals with identification of wildlife parts and products seized from a person and forwarded to the Forensic Lab for analysis. Actual scene of crime is not known and hence only the samples along with suspect in question have to be investigated. This would lead to incomplete investigation of offence cases. It is a well-known fact that Wildlife crimes falls into a category of highly

organized crimes involving a strong syndicate of poachers, local consumers, middle-man, small town processors, financier and traders, transporters, agents and customers/buyers, etc. In any wildlife offence case, wildlife may be a victim and hence it is given prime focus but the human interface of the offence case is always neglected. At times, it is difficult to identify wildlife parts and products and hence the case becomes weaker. In such cases, investigator needs to look for evidences related to human involvement i.e. biological, physical and chemical evidences.

Looking into such complicated cases, it is necessary for wildlife forensic laboratory to work in close coordination with human forensic laboratory. Despite the major scientific and technical advancements in the field of wildlife forensics, there are few areas still unturned and there is a strong need to establish the laboratory facility and protocols for Genomics analysis, toxicological analysis, ballistic examination, etc. of wildlife samples in case of illegal hunting/ poaching. At times cases are reported in which animals are either been electrocuted and intoxicated using poisonous material like poisonous seeds, chemical poisons, etc.

Some of the major challenges faced while investigation of wildlife crime cases are:

- Lack of Standardized wildlife reference sample repositories and database and those data of genetic profile available on NCBI may contain false positive rendering mis interpretation of unknown samples.
- Neglecting the Investigation of Human related evidences and concentrating on examination of seized wildlife parts and products
- Lack of skilled man-power, with only few experts trained in India, that has competence in investigation of wildlife offence cases
- Need for sensitization amongst officials from Forest department, veterinary officers, police officers, etc for scientific collection of biological evidences
- Unlike Human forensics where comparatively there are hundreds of human forensic science laboratories in India, there are just five laboratories dealing with examination of wildlife offence cases
- While human forensics has defined sets of biological evidences that originates from just on species i.e Human (*Homo sapiens*); wildlife forensics offers spectrum of evidence from wide array of trafficked species world wide rendering requirement of trial and testing in every different type of wildlife

articles and challenges thereafter because of lack of reference standards or protocols.

- Wildlife Forensics has always been paid less attention compared to human forensics in terms of funding, infrastructure development, training, research and development and many such important parameters.

Key points regarding Illegal wildlife trade

- There is an unprecedented decline in some of the flagship species like Tigers, Rhino, Elephant, Bears, Pangolins, Musk deer, etc, mainly because of the demand of their parts and products in traditional Chinese medicine, trophy material or for many more reasons apart from lesser known flora and fauna in India.
- Apart from top three high rated crimes in the world, i.e. Narcotics, illegal arms trade, and human trafficking, Wildlife crime is the fourth largest illegal crime. Estimates of illegal wildlife trade is from USD 7-13 billion per year making wildlife crime the fourth largest illegal global trade, behind only narcotics, counterfeiting, and human trafficking. (UNODC, 2020)
- In order to address the risk of Zoonotic diseases through wildlife trade, it is important to restrict the open market trade of wildlife parts and products
- Stringent implementation of regulations of The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) will help in ensuring restricted wildlife trade and better conservation of charismatic wildlife species.

3. Key Technological Advancements

The application of forensics to wildlife crime investigation routinely involves genetic species identification based on DNA sequence similarity. Until recently, the protocols for molecular diagnostics were expensive and time-consuming, making this approach justified only in cases when morphological identifications were difficult. Molecular tools have become an indispensable part of innumerable systematic and conservation-based studies (Hillis et al., 1996). Task of identifying species in wildlife trade becomes more precarious and accurate identification is often impaired where the samples are degraded and difficult to identify using morphological techniques. In such cases, it is necessary to process and analyze the sample using robust molecular biology techniques like DNA sequencing. To improve our ability to detect, monitor and control the trade in wildlife and wildlife products, more accurate and efficient methods of species identification are required (Challender et al., 2015).

Wildlife offence cases reported and analyzed till date are solely based on morphometric techniques and DNA based examination. Apart from DNA and morphometric facility, there is a need to take help from following divisions of human forensic facility to effectively analyze the case and help the justice system. Most important advantage of establishing the State-of-Art Wildlife Forensic Facility would be the privilege of utilizing the existing facilities for various domains like Forensic Biology, Forensic Physics, Forensic Toxicology as well as Cyber Forensics that are already set-up at various FSL`s in India.

Morphological and DNA based examination

Identification of species as well as establishing individual identity are two major questions to be addressed in wildlife offence cases. Wide spectrum of sample types may be sent for analysis ranging from skins, tissue/meat, bones, antlers, hairs, blood spots, etc. and most of samples are in degraded because of adverse field condition or preservation techniques. To deal with such sample analysis, laboratory should be equipped with sophisticated instrumentation like DNA Sequencer and other supplementary instrumentation facility. Samples like hairs, antlers, bones, skulls, Ivory, claws, canines, etc. can be analyzed using established protocols using microscopy and Morphometry techniques.

Examination of Wildlife articles using radiological and Anthropometric techniques

Illegal wildlife trade of bones of different species is very common. Osteological features retain species specific characteristics. Examination of bone characteristics helps to identify species, sex and age group of the animal.

X ray radiograph provides help in investigation of firearm injuries. By a thorough examination of radiographs, it can be determined that whether the animal was unlawfully injured or killed. The use of radiographic techniques to detect fraud and forgeries in the art world has great historical precedence viz. products made up of bone, antler and ivory. Following instruments are required in forensic osteology - complete set-up of digital X-ray radiography unit with computer assisted digital osteometric boards, calipers, digital camera with computer assisted facilities. Computed tomography is a very imported technique which uses X-ray energy to generate 3D information of the anatomy in the form of 2D slices or axial views. The parameters that can be identified with the help of axial

slice images are gunshot trauma, haematoma, tension pneumothorax (possibly with an associated mediastinal shift), fractures, strangulation, and detection of foreign bodies and air embolisms (Thomsen *et al.*, 2009; Gibb, 2008; Jeery *et al.*, 2008; Bolliger *et al.*, 2008).

Application of Forensic Chemistry, toxicology and analytical instrumentation techniques

At times, cases are reported in which animals are killed by poisoning, may be with use of poisoned bait, poisonous seeds like nux vomica or *Abrus precatorius*. Routine wildlife forensic facility does not have toxicology analysis expertise but this would prove important in establishing cause of death from viscera content in few cases. Sometimes, bunch of animal skins are seized in single consignment from poachers and cause of death or site is not known. In such cases, investigators should look for poisonous seeds or any other local/standard poison used and that can be analyzed using analytical techniques like Gas Chromatography-Mass Spectroscopy (GC-MS), High Performance Liquid Chromatography (HPLC), etc. Some of the finished/polished/furnished wildlife parts and products are such that their morphometric parameters are lost, source of DNA extraction is lost and only option left is to analyze the samples using analytical techniques like GC-MS, HPLC, FT-IR, FT-Raman, etc.

Electrocution of wild animals is also practiced in areas surrounding agricultural farms and nearby protected areas. In such cases, skin piece from the affected carcasses can be analyzed for presence of metal deposition from wired fencing using EDXRF and other techniques.

Role of Digital Forensics in tracking wildlife criminals

Since a group of people are involved in committing wildlife offence cases, it is inevitable that the communication/information between poachers to middle man, processors and consumers would be transmitted through electronic media. Cyber forensics facility plays instrumental role in analyzing digital evidences such as SIM cards, mobile phones, Emails, laptops/computers, hard disk used for organized crime and may prove important to track the actual person behind the crime and a vital link in solving offence cases. Cyber surveillance would also enable to monitor and prevent online sale of wildlife parts and products over internet. Voice Spectrographic identification from recorded phone calls would enable to trace the individual identity of person/s involved in wildlife crime.

Digitalization of wildlife forensic facility

Digitalization of documentation and Electronic surveillance is an important parameter for smoother functioning of Forensic laboratory. It is suggested to introduce Radio Frequency Infrared Device (RFID) technology which enables better security surveillance and smoother functioning of forensic facility. Key reasons for installation of RFID are its ability to assign unique barcodes to individual specimen, assign location to the specimen, accurate and instant tracking and tracing capability using the unique identity, recording the detail specimen related activity and event logs, and maintain chain of custody. RFID would enable us with minimal error during data entry of aspects involved while dealing wildlife offence cases enhance work productivity and accountability, improvised security and better regulatory and protocol compliance monitoring.

All the record related to case files will be accessible through authorized person with details of in and out file entry using digital record of entries via barcode system. It is recommended to introduce and install biometric finger print scanner at entry of each divisions of laboratory to keep a check over personal access to the laboratory, control to analytical areas, the clear delineation between areas for administrative/clerical work and laboratory areas used for testing. It is also proposed to establish the online database management system for reference repository of samples as well as case samples, which would enable for smoother tracking as well as utilization of laboratory facility.

Laboratory sterilization, hygiene and precautions

In order to establish a State of Art laboratory, environmental conditions, must be appropriate for the tests being performed and environmental conditions must not invalidate the results or otherwise adversely affect the required quality of any measurement. Specific considerations must be given to environmental factors such as: Biological sterility (e.g., a DNA profiling laboratory must have a UV sterilizer and light source for regular sterilization of working laboratory room, dust free environment should be set up to avoid any cross contamination due to aerosol particles. Other parameter that needs to keep in mind while setting up a laboratory is: temperature and humidity, stability of electrical supply, sound and vibration levels etc. The built-up and architecture of the laboratory should be one of the exemplary standard that would set-in high standards for futuristic laboratories in India and globally.

Detailed crime scene investigation would lead to recovery of suspected documents that may include maps, local bills, newspapers, currency notes, diaries with information on crime execution and miscellaneous literature that may be linked to crime scene. It is difficult to commit a crime without leaving traces of fingerprints at crime scene. Looking for fingerprint as evidence and establishing a database for fingerprints of wildlife offenders would be crucial in identifying perpetrator.

Scientific understanding of the Current SOPs and practices in the relevant discipline

With the technological advancements, digital platforms, artificial intelligence, drone technology, communication media, and sophistication in the field of scientific investigation new avenues are opened up to help in combatting wildlife crime. With the advent of new technologies, criminals are also becoming equipped with latest tools and have switched to digital platforms, to decipher their identity while executing wildlife crime. Advanced technologies are harnessing law enforcement officials to combat wildlife trade in more prolific manner than earlier, however, lack of skilled man power and effective training is a bottleneck in combating illegal wildlife trade.

Internationally, trafficking of wildlife parts and products is a highly lucrative market with high profit and less risk of conviction, rated as fourth largest crime behind narcotics, illegal arms trade and human trafficking ((IUCN, 2016; CITES, 2013;TRAFFIC, 2022). There are several driving forces of wildlife crime, including demand for local consumption, economic profit and poverty (Akinsorotan et al., 2020; Duffy et al., 2016), the survival of humans involved in the crime (Travers et al., 2019), possession or use of wildlife for socio-cultural rituals (Shao et al., 2021), bush meat (Rija et al., 2020), trophy hunting (Sollund, 2020), human-wildlife conflicts (Didarali et al., 2022; Viollaz et al., 2021), Wildlife crime has been posing a significant threat to animals worldwide (UNODC, 2020).

4. Policy Recommendations for effective Investigation of Wildlife Crime Cases

4.1.Data management and establishment of reference repository of biological sample

Wildlife forensic science predominantly relies on availability/accessibility of

reference sample against which comparison has to be made to identify the evidence. Reference materials are typically in the form of physical samples, but may also be held digitally as reference data (Rob Ogden, 2010). Efforts are required to generate the reference repositories of samples through sensitization amongst various enforcement agencies across India. Coordination and liaisoning with various forest departments across India would be crucial in order to have good pool of reference samples repository at centralized laboratory and generate expertise in maintaining the biological sample repository .

In addition, the wildlife articles, parts, products & case properties received from different enforcements agencies and the forest departments after proper scientific analysis and subsequent to disposal of cases in court, can be converted into reference repository that can be used for research and development, training and cross reference matching. These articles will be highly important material for conducting teaching, training and conducting courses on wildlife forensics and crime control and therefore considering the present and forecasting the future requirements, National Forensic Sciences University is already looking forward to setup a strong room/reference repository with modern safety measures, quality checks and fire extinguishers to avoid any future mishap or accidental damage to valuable reference samples.

As a part of initial phase of the facility set-up, reference biological samples of various species are required to be subjected to DNA extraction/Isolation, Polymerase Chain Reaction as well as DNA Sequencing. Protocols need to be standardized to identify spectrum of samples; may it be in original form or finished product/article. Reference DNA and genomic database of various flagship species that are being traded illegally, need to be generated and stored in a dedicated cold-storage facility as well as bioinformatics data facility.

4.2. Quality control and standardization of SOP's

Wildlife forensics should be more centered towards identification of species and corroborative evidences for its disposal in court of law through scientific proceedings and specified protocols meant for species in question A very high standard for crime scene investigation, sample processing in lab, data interpretations and validation must be implemented as followed in human forensics (e.g. NIJ/NIST standards). Currently, examination of wildlife evidences, when examined using DNA techniques, relies on use of Universal mitochondrial markers, like Cytochrome b, Cytochrome oxidase I, D-loop, etc.



Though these markers are robust in amplifying most of the known species, it is necessary to always submit the report that is generated based on multiple marker system rather than relying on single mitochondrial markers.

Undertake necessary steps for “Accreditation of Wildlife Forensics” Lab by the National Accreditation Board for Testing and Calibration Laboratories, Department of Science and Technology, Ministry of Science and Technology, Govt. of India, New Delhi and other important accreditation that ensures quality check at various level of analysis and investigation. NABL accreditation which is a hallmark for scientific credibility of experiments performed in forensic science laboratories is required for each wildlife forensic laboratories and incorporate latest technology in training for early detection of crime and for prevention of crime as preventive forensics. After the laboratory is Set-up and functioning in its fullest capacity, attempts should be made to procure accreditation under ISO/IEC as well as various other accreditation as per requirement and applicability. Such accreditation of the laboratory will help in enhancing as well as maintaining the high standards of laboratory methodologies, proficiency testing, integrity of the data generated in the laboratory, transparency in the work-flow and global out-reach to the potential users of the facility.

Procurement of License, Notification in Gazette as certified Wildlife Forensic expert and nodal centre for possession of wildlife articles for display during training program as well as for research and development activities.

4.3. Research and Development in Wildlife Forensics

As a perceived fact, wildlife forensic laboratories are referred wide diversity of case samples, that requires trial and testing of various protocols. Each case referred is to be treated as a new challenge and as far as wildlife forensic examination is concerned, the model “One Size fits for All” cannot work and numerous SOPs are required to be developed for examination and analysis of wildlife articles seized under offence cases. Hence, there is also a requirement of developing protocols for examination of wildlife articles, especially finished products and few challenging articles, that requires undertaking extensive Research and Development activities. One of the challenging aspect of wildlife forensics and conservation biology is to attract funding. Funding agencies should encourage awarding more funds and research projects schemes to be implemented in the field of wildlife forensics, conservation biology and allied discipline.

4.4. Interdisciplinary collaborations

During the path of developing Wildlife Forensic facility, it would be necessary to indulge into collaborative efforts to investigate wildlife offence cases by signing MoU between other nodal agencies in India and internationally. Though it is well perceived fact that India has the capabilities of undertaking analysis of offences cases with the help of experts in various domains, but in the field like Wildlife Forensics, there would be requirement of collaborative efforts in terms of ecological and taxonomic know-how of the specimens in question, intelligence gathering and use of traditional knowledge in the mentioned field. Aforementioned tasks can be conducted smoothly by collaborating with some of the peer institutes in the field of wildlife conservation.

Mostly, the collaborative work will involve government organizations working in India as well as various forest departments across the country. Some of the organizations like National Tiger Conservation Authority (NTCA), Wildlife Crime Control Bureau (WCCB), etc. are considered important in terms of formulating policies. So MoU with these organizations will help in smooth functioning and conduct of the wildlife forensic laboratories once sanctioned and established at appropriate locations in India.

Further, MoU with some of the premier research institutes in India will also give a new dimension of student exchange program that will help in enhancing the skills of students and researchers.

Therefore, it is proposed to expand and strengthen the facility of Wildlife forensics in India utilizing existing resources as well State of Art instrumentation facility, which would enable us to provide better support in conservation of wild species and strengthen wildlife enforcement in India. Establishment of such facility will take Wildlife conservation efforts in India to new pinnacles as it would be the first of its kind and only dedicated Wildlife Forensic Facility in South-East Asia dealing with almost all types of wildlife offence cases including, morphometry, DNA based examination, toxicological analysis, entomological examination, analytical examination as well as basic ballistic examination, all under one roof. National Forensic Sciences University, Gandhinagar definitely has potential to establishes wildlife forensic facility of such highest standards.

Role of CITES in curbing International Trade of Wildlife

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is basically an international agreement that restricts the trafficking

of wildlife parts or products (animal and plant origin) through international trade and makes sure that these species are not threatened for their survival. Since wildlife crime is transnational crime where there are transit routes through porous borders, extensive efforts are required through international cooperation in order to safeguard species from illegal wildlife trade (CITES, 2018).

5. Ethical and legal Considerations

In the field of Wildlife Forensics and Conservation biology, procedure is defined for procurement of biological samples that originates from non-human species as per Biodiversity Act, 2002 and Wildlife (Protection) Act, 1972 of India. However, all the samples to be collected/preserved for any research and developmental activities need to be collected adhering to ethical guidelines after procurement of permission from competent Internal Ethical Committees of various scientific organizations.

Since, the human genetic data is different from non-human genetic profiling, DNA data that is generated can be uploaded on NCBI which is a public database after due curation by experts in the domain and also avoiding junk or homologous data on public portal.

In order to assess the identity of species and its affinity with closest relatives, phylogenetics is an important tool that is widely used in various conservation genetics laboratories across world. The gene sequence data of various species uploaded on NCBI can be cautiously utilized to compare the unknown sequence and generate the phylogenetic tree for better consensus on DNA based report to be prepared.

6. Capacity building, training and sensitization of officials investigating wildlife crime cases

Skill development and training in forensic science is an integral part of manpower development in forensic domain. Scientific analysis of evidences requires highest levels of skills and conditioning. Addressing the questions and problems pertaining to species identification in wildlife offense cases, ground intelligence networking, cases related to import and export of exotic species and species listed under Wildlife (Protection) Act, 1972 of India, cases of food forensics, etc., it is very important for every in-service official to have basic knowledge of tools and techniques used in Wildlife crime investigation and the underlying principles in wildlife forensics. In particular, the sample

collection, storage, sealing, forwarding etc. as well as the basics of DNA-based species identification and authentication system. Due to absence of any hands-on training facility in the country on these applications, the skills of relevant personnel still need to be updated for both, the trainee as well as working/senior officers. Training program/Module on “Wildlife Forensics for Indian Forest Service (IFS)” officers should be mandatory as a refresher course or career advancement schemes for IFS officers.

- Training program/module on Wildlife Forensics and Conservation biology for DCF/DFO/ACF of various forest departments in the country should be organized at regular intervals.
- Likewise, many such customized modules as and when required can be prepared depending on demand of various enforcement agencies working in the field of wildlife conservation.
- Since wildlife crime is not restricted within forest areas, and frequency of detecting wildlife crime during transit/trafficking across borders is more, officials from Army, Navy, Coast Guards, Air-force, Para-military forces, CRPF, etc. need to be sensitized about the potential trafficking route of Wildlife parts and products and effective ways to mitigate such issues in India and across borders.

The main focus of training and skill development is to foster next generation of forensic scientist as a work force to support criminal justice delivery system. The framework of training and skill development will help to achieve this goal. With the expansion to national institute, To prepare a Perspective plan for the development of wildlife forensics technology in India, following points need to be addressed:

- (i) To establish close linkage with national and international institutions of repute in the wildlife forensic technology,
- (ii) To create the required infrastructure (work space, storage facility, reference samples and database,
- (iii) To become proficient in species identification of Indian vertebrates (Mega Fauna and lesser known fauna as well) using external morphological characteristics, DNA Technological advancements.
- (iv) Begin accumulating and storing tissue samples for eventual use in biochemical forensic analysis,
- (v) To disseminate the acquired knowledge to users.

Workforce Development and requirement of skilled man-power

With very few experts currently known in the field of wildlife forensics, that has proven competence, there is an extensive requirement for fulfilling the acute shortage of wildlife forensic experts in the country. Dedicated, staff should be recruited for examination of wildlife crime cases covering the expertise in the field of DNA and morphometric examination. Recruitment rules should be amended and relevant experience and specialization degree need to be added for recruitment of skilled man-power in wildlife forensic facility

7. International Cooperations

Wildlife crime is considered to be one of the most organized crime and a group of syndicates are active including local village man hired for poaching the animal, middle man involved in processing of wildlife article to the end user sitting remotely who demanded wildlife part or product for intended use. Most of the wildlife crimes are committed elusively in remote forest area, many times, the act goes unnoticed, however, mostly the wildlife articles are seized during transit while trafficking from one place or country to other. It is necessary to have inter agency coordination for effective intelligence gathering and information dissemination, and intensify patrolling in susceptible areas in forest landscapes. Provision should be made to establish the database of repeated and notorious offenders and the same can be shared with intelligence wings of adjoining countries. Many conventions like CITES, NGO`s like TRAFFIC- India, Intergovernmental organizations like INTERPOL, Wildlife Crime Control Bureau, SAWEN (South Asia Wildlife Enforcement Network), ASEAN-WEN, should have close coordination to share information related to wildlife trafficking, forensic intelligence and susceptibility of flag ship species from getting trapped in wildlife crime.

Rather than restricting to species identification of wildlife parts and products, it is also necessary to trace the geographic origin of those contraband articles, that can help in tracing the roots of actual place of crime and narrowing down the investigation to catch hold of organized syndicate by breaking the demand-supply chain. These requires efforts to be put in by multiple agencies.

In order to maintain the highest standards of examination in wildlife forensics, it is suggested to make it mandatory for all the forensic scientist for undergoing proficiency testing , individual certification and accreditation of the laboratories.

Conclusion

“Corruption has been one of the root cause of several transnational crimes that are executed across borders, and ultimately affecting spectrum of CITES-listed and non-listed species. Lack of unified consensus on defining wildlife crime has posed challenges for law enforcement agencies, wherein if one country prohibits trafficking of wildlife parts and products, other may allow.

Given the ambiguities inherent in defining Illegal wildlife trade, quantifying illegal wildlife trade is challenging and utmost difficult to execute with accuracy without clarity at international level. However, it is recommended to established centralized database of illegal wildlife trade in India, wherein we have defined cases falling under wildlife crime and include cases based on detection, reporting, examination and try to reinvestigate few underreported cases as well. There is a need of coordinated efforts amongst different law enforcement agencies to understand dynamics of illegal wildlife trade, supply chain and strategies to mitigate the trade through effective enforcement of laws.

Unprecedented illegal wildlife trade can be controlled through establishment of state of art dedicated wildlife forensic facilities in India, recruitment of skilled man power, extensive training and skill development programs, accreditation of wildlife forensic laboratories, extensive research and development and informed policy making in the field of wildlife forensics.

Equal weightage to that of human forensics should be given to wildlife forensics, in terms of infrastructure development, funding and prioritizing the field to curb unabated wildlife trade before we lose our valuable wildlife resources.

- Henceforth with the ever increasing crime rate, high-tech techniques deployed by criminal in execution of crime, it is now a high time to accelerate the process of criminal investigations through high-end forensic techniques and skilled expertise. Further with the projected crime rate in future, need of forensic expertise, it is evident that there will be a huge demand and need of trained wildlife forensic experts in the country.
- Simultaneously the young generation should also be encouraged to get attracted toward one of the most challenging and fascinating field of wildlife forensic science by imparting the best academic programmes aided by theoretical and practical exposure to the best possible forensic facilities available in India and globally with close coordination with FSL's across country.



- It is anticipated that the pool of experts trained at various academic organizations of Wildlife Forensic Sciences in India, they would get an equal opportunities for employment in FSL`s and allied enforcement agencies in India.
- It is also envisage in fostering the need of research and development in the field of wildlife forensic science and allied field with utmost quality and hence setting up state-of the-art research centers would be encouraged with specific objectives.
- Further, in-service officers also need to be trained in their respective areas of expertise and also mandatory refresher courses need to be included as a part of career advancement schemes that would help in improving quality of wildlife forensic investigations, increasing conviction rates and ultimately improving criminal justice delivery system for better law enforcement in India.

Chapter 8

Medicolegal Investigation - Non-Invasive Procedures for The Criminal and Routine Human Identification: Prospective and Prolific Determinants for Profiling

Dr. G. Rajesh Babu¹ and Dr. Abraham Johnson²

1. Introduction

In any cases of mass disaster/mass fatalities, there are high chances that the bodies become unidentifiable. Subjected to various environmental conditions even in specific conditions like burns and drowning cases the situation becomes complex. The identification becomes difficult due to non-availability of fingerprints and DNA. Even in certain conditions where the evidences are available, there is still difficulty due to non-availability of specific databases for comparison purposes.

Medico-legal investigation for identification is a vital aspect of forensic science that plays a crucial role in determining the cause, time since death and manner of death apart from the identification of the victims. This branch of forensic science involves the collaboration between forensic experts, medical professionals and law enforcement authorities to establish the identification and the resolution of the case under question. These investigations play a crucial role in the justice delivery system as they provide valuable evidence that can assist in ensuring fair legal trials and outcomes.

2. Current Landscape of Medicolegal Investigation in Human Identification

Autopsy Procedures: Autopsies, also known as post-mortem examinations, are performed by forensic pathologists. They involve both external and internal

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examinations of the body. The external examination assesses any injuries, scars, or other visible marks on the body's surface. This also includes the peculiarities and the remarkable findings if any, for the purpose of resolving the issues pertaining to the crime against individuals and the question of identity. The internal examination involves the analysis of the organs and tissues to identify any abnormalities that may have contributed to the cause of death and to establish the identification.

Forensic Toxicology: It is very useful in investigations in cases of death due to poisons or substances ingestions that lead to death. It helps to establish the substances those have been administered result in the death or secondary to the cause of death . or causing abnormalities or morbidities among the individuals. It can also detect the poison in contents of the stomach, blood samples, etc or in any other biological tissues. This also signifies the detection of the any unusual substances or unusual quantities present in the physiological systems of nay individual that has caused morbidity or mortality . in addition to this there is scope for understanding any influence of substances those are constantly exposed to the individuals by way of life style, habits, occupation and also due to the environmental factors.

Forensic Anthropology is a specialized branch of forensic science that focuses on the analysis of human skeletal remains to provide critical insights in investigations which is ultimately needed for the identification of the individuals (of such deceased). Forensic anthropologists play a pivotal role in cases involving unidentified or decomposed bodies, victims of mass disasters, and in any criminal investigations. This signifies the in the estimation of age, determination of sex, presenting the ancestry, estimation of stature and also individualizing the characteristics from the skeletal remains, aiding in victim identification and the reconstruction of events leading to death. Additionally, this is also significant in assessing trauma, pathology, and post-mortem changes to determine the cause time and manner of death. With a deep understanding of human anatomy, osteology, and taphonomy, forensic anthropology yields vital information to officials of law enforcement, medical examiners, and the judicial system. This is ultimately helping to solve crimes and also in helping the families to reunite with the lost individuals and also to the deceased.

Forensic Odontology - Forensic Odontology, or Forensic Dentistry, is a specialized branch of forensic science focused on identifying individuals through dental records and examining dental evidence in legal contexts. Forensic



odontologists, trained dental professionals, play vital roles in disaster victim identification, criminal investigations, and medicolegal cases, using dental records for positive identifications, analyzing bite marks for crime-solving, estimating ages of unidentified remains, and providing expert testimony in court. In any case of the disaster victim identification, the scope is enhanced with the antemortem data of the dental records. There is further obligation of developing and maintaining such data among the practitioners. Claims and compensation for the animals bite may be resolved through this technology in the needy circumstances and cases pertaining to such scenarios.

Forensic Nursing – It is a specialized branch of nursing that combines healthcare expertise with legal knowledge to provide compassionate and evidence-based care to individuals involved in legal matters, crime victims, or those who have suffered trauma. Forensic nurses play a vital role in the criminal justice system by collecting and preserving crucial evidence, offering victim-centered care, conducting sexual assault examinations, advocating for patients' rights, and providing expert testimony in legal proceedings. Their interdisciplinary collaboration with law enforcement, forensic experts, and legal professionals ensures comprehensive clinical care, psycho social support for victims, making them providers of essential mediation in the pursuit of justice and a comprehensive care and management for those affected by violence, destitute, despair, distressed and trauma. As a first professional to notice and examine the victims of any unforeseen events and circumstances, forensic nurses play a vital role in medicolegal, medico social, psycho social and clinical obligations and comprehensive management.

Forensic Archaeology is a specialized field within forensic science that employs archaeological principles and methods to locate, recover, and analyze physical evidence in legal investigations, particularly in cases involving buried or concealed human remains and related crime scenes. Forensic archaeologists meticulously excavate and document crime scenes, preserving the integrity of evidence while unearthing critical clues that can aid law enforcement and forensic experts. Their expertise in stratigraphy, context analysis, and taphonomy (the study of decay and preservation) allows for the reconstruction of events, identification of victims, and the determination of key forensic information such as cause and manner of death, trauma analysis, and burial practices. By applying archaeological techniques to forensic contexts, forensic archaeologists contribute significantly to the resolution of criminal cases and the establishment of justice.



Humanitarian Forensics is a specialized field that combines forensic expertise with humanitarian efforts to address the critical needs of victims in mass disasters, armed conflicts, and human rights abuses. It involves the ethical and systematic collection, analysis, and interpretation of evidence, including the identification of deceased individuals, missing persons, and victims of violence or atrocity crimes. Humanitarian forensic experts work diligently to provide answers to families searching for their loved ones, to support human rights investigations, and to contribute to the process of justice and accountability. By bridging the gap between science and human rights, humanitarian forensic practitioners offer solace to grieving families, shed light on atrocities, and uphold the principles of truth, justice, and dignity in the face of unimaginable tragedies. Not only establishing the identity of the living and the dead the humanitarian forensic professionals ensure the union of the missing/ lost families, normalcy in psychosocial, clinical, psychological socio cultural parameters. They are able to achieve comprehensive homeostasis in physiological and psychological traits among the affected victims (of any unforeseen events or circumstances such as political, geographical, demographical and social conflicts or mass fatalities and forced migrations, victims of human trafficking. It is also serving the purpose of ensuring the social security provided by the government by way of ensuring the claims and compensations due to the affected families through the identification of deceased in an absolute and flawless scientific manner

3. Key Technological Advancements

- **Superimposition Techniques** - Superimposition techniques in forensic science involve overlaying images of a person's remains (such as a skull) with ante-mortem (pre-death) images, often derived from photographs or radiographs, to aid in the identification process. These techniques have seen advancements due to the integration of advanced imaging technologies and computational methods. Moreover, biochemical analysis also narrow down the identification process. Anthropometry, the measurement of human body characteristics for identification purposes, has seen advancements in recent times that have refined its application. While traditional anthropometric methods, such as height, weight, and facial proportions, remain relevant, modern technology has expanded the scope of anthropometric analysis.
- **3D Imaging and Reconstruction:** Advances in three-dimensional imaging technologies have improved the accuracy and precision of identification. High-resolution 3D scanners and imaging techniques allow for more detailed

capture of objects and easier comparison with reference models. This enhances the chances of the identification to near accuracy or certainty in absolute identification

- **Software Development:** Improved / updated software with advanced algorithms for aligning images, adjusting for scale and orientation differences, and quantifying the degree of overlap between objects aid in accurate human identification.
- **Geometric Morphometrics:** Geometric morphometrics involves the statistical analysis of shape and form. This technique has been applied to superimposition, enabling the quantification of shape variations, and helping to identify subtle differences or similarities. This enhances the scope for the probable identification based on microscopic and macroscopic assessment and resultant profiling of the individuals.
- **Biomechanical Analysis:** In forensic anthropology, biomechanical analyses consider the biomechanics of how muscles, tendons, and ligaments interact with skeletal structures, aiding in facial reconstructions and identifying unknown remains. Not only these systems used for the identification but also they impart the solutions for the question on the racial, regional, demographic and geographical affiliation of the subjects.
- **Integration of Multimodal Data:** Superimposition techniques are increasingly integrating data from various sources, such as CT scans, radiographs, and photographs. This multimodal approach provides a more comprehensive view for experts to make informed decisions.
- **Three-dimensional (3D) scanning technology** has revolutionized medicolegal investigations by providing precise and non-invasive documentation of crime scenes, human remains, and physical evidence. This cutting-edge technology captures comprehensive 3D models of forensic scenes, allowing investigators to preserve critical details, accurately measure distances, and revisit the scene virtually at any time. In the context of human remains, 3D scanning aids in the documentation of bodies, injuries, and trajectories of projectiles, facilitating forensic analysis.
- **Three-dimensional (3D) printing** has emerged as a valuable tool in medicolegal investigations by enabling the creation of physical replicas of anatomical structures, evidence, and crime scenes. In forensic anthropology, 3D printing is used to replicate skeletal remains for analysis and education, aiding in victim identification and cause of death determination. Additionally, it allows for the recreation of crime scene details, such as weapons, wounds, offering tangible, courtroom-ready exhibits for legal proceedings.

- **Radiographs**, commonly known as X-rays, play a crucial role in medicolegal investigations by providing invaluable insights into identifying injuries, fractures, foreign objects, and anatomical anomalies in human remains. They are instrumental in forensic pathology, aiding in the determination of the cause and manner of death. Additionally, radiographs assist in the examination of skeletal remains, allowing forensic experts to assess age, sex, ancestry, and individualizing characteristics, thus contributing to victim identification. Recent advancements in radiography have significantly enhanced its role in medicolegal investigations. Digital radiography and computed tomography (CT) scanning have replaced traditional film-based methods, offering higher image resolution, faster results, and enhanced storage capabilities. 3D reconstructions from CT scans enable precise visualization of injuries, allowing forensic experts to better assess the extent of trauma. Mobile X-ray units and portable CT scanners have facilitated on-site examinations in mass disasters and crime scenes. Radiographic evidence is admissible in court and frequently used to support expert testimony, helping medical, forensic and legal professionals understand the extent of injuries, trauma, or pathology, ultimately enhancing the accuracy and credibility of findings in medicolegal cases.
- **Virtual autopsy** represents a cutting-edge advancement in the field of medicolegal investigations. Instead of traditional post-mortem procedures involving invasive dissection, virtual autopsies employ advanced medical imaging techniques like CT scans and MRI to create detailed 3D reconstructions of the body's internal structures. This non-invasive approach enables forensic pathologists to examine organs, bones, and tissues with remarkable precision, identifying injuries, trauma, and potential causes of death. Virtual autopsies are particularly valuable when handling cases where a traditional autopsy may not be feasible or is ethically and culturally sensitive. Additionally, this technology allows for digital preservation of evidence, facilitating interdisciplinary collaboration among forensic experts. Virtual autopsies represent a transformative tool that enhances the accuracy and efficiency of medicolegal investigations, while respecting the dignity of the deceased and addressing the evolving needs of modern forensic science. This is probably the solution for the satisfying needs of both legal and social obligations by way of making non destructive / non invasive procedures for the entire range of examinations of the internal organs.
- **Cross-Disciplinary Collaboration:** Collaboration between forensic experts, computer scientists, engineers, and other specialists has led to innovative approaches. This interdisciplinary collaboration fosters the development of novel techniques and technologies.



- The integration of **Virtual Reality (VR)** and **Augmented Reality (AR)** technologies, along with **Machine Learning (ML)** and **Artificial Intelligence (AI)**, has brought transformative capabilities to medicolegal investigations. VR and AR enable investigators to reconstruct and immerse themselves in crime scenes, enhancing the understanding of spatial relationships and aiding in evidence documentation and visualization. ML and AI algorithms analyze vast datasets, swiftly identifying patterns and anomalies in medical records, forensic evidence, and CCTV footage, expediting the investigative process. These technologies assist in facial recognition for victim identification and help predict injury causation, while automating the sorting of vast medical records to identify crucial case details. As a result, these advancements collectively enhance the efficiency, accuracy, and comprehensive nature of medicolegal investigations, providing invaluable tools to forensic experts and legal professionals in the pursuit of justice.
- **Forensic Facial Reconstruction** is a multidisciplinary technique to recreate the facial appearance of unidentified human remains. This method combines anatomical knowledge, anthropometric analysis, and artistic skills. Initially, forensic experts analyze skeletal remains to determine the size, shape, and position of facial muscles and tissues. Then, the expert utilizes clay or digital software to sculpt a facial approximation on the skull, considering factors like age, sex, ancestry, and unique facial features. The goal is to produce a facial reconstruction that closely resembles the individual's appearance in life. This visual representation aids in the identification of unknown individuals and is especially valuable in cold cases or cases where traditional identification methods have proven unsuccessful. Forensic facial reconstruction serves as a powerful tool in human identification, offering a face to those who have remained nameless for far too long and providing closure to families and communities affected by tragedy.

4. Implementation of Inter-operable Criminal Justice System (ICJS) regarding the domain:

The Inter-operable Criminal Justice System (ICJS) is a concept aimed at enhancing communication and data sharing among various components of the criminal justice system, including law enforcement agencies, courts, correctional facilities, and other relevant stakeholders. Implementing an ICJS in the context of forensic investigations and criminal justice involves integrating technology, data, and processes to improve efficiency, accuracy, and collaboration. Here's a general roadmap for implementing an ICJS for the domain:



- a) **Needs Assessment and Stakeholder Involvement:** Identify the needs, challenges, and goals of different stakeholders within the criminal justice system, including law enforcement, forensic labs, courts, correctional facilities, and legal professionals. Engage them in the design and implementation process to ensure their needs are addressed.
- b) **Technology Infrastructure:** Establish a robust technology infrastructure that supports secure data sharing and communication. This might involve creating a centralized database or a network that allows authorized users to access and share information.
- c) **Data Standardization and Integration:** Standardize data formats, terminologies, and codes across different components of the criminal justice system. This ensures that information can be shared and understood accurately across agencies.
- d) **Information Sharing Protocols:** Define clear protocols for sharing information among different stakeholders. Establish rules for data access, permissions, and data security to maintain privacy and confidentiality.
- e) **Electronic Case Management System:** Implement an electronic case management system that enables seamless tracking of cases throughout the criminal justice process. This system should allow different agencies to update and access case-related information in real time.
- f) **Biometric and Forensic Data Integration:** Integrate biometric data (such as fingerprints, DNA profiles) and forensic evidence (crime scene photos, lab results) into the system. This enables investigators and legal professionals to access critical evidence digitally.
- g) **Inter-Agency Communication:** Develop communication tools and platforms that enable real-time communication among different agencies. This could include secure messaging systems or video conferencing for virtual meetings.
- h) **Training and Capacity Building:** Provide training to personnel across different agencies on how to use the ICJS effectively. This includes training on data entry, access controls, and navigating the system.
- i) **Quality Control and Audit Mechanisms:** Establish quality control measures to ensure the accuracy and integrity of data entered into the ICJS. Regular audits can help identify and rectify errors or inconsistencies.
- j) **Pilot Testing and Phased Implementation:** Begin with a pilot program involving a specific geographic area or subset of cases. This helps identify challenges and fine-tune the system before full-scale implementation.



- k) **Legal and Policy Framework:** Develop clear policies and legal frameworks governing data sharing, privacy, and security. Ensure that the ICJS complies with relevant laws and regulations.
- l) **Monitoring and Continuous Improvement:** Continuously monitor the performance of the ICJS, gather feedback from users, and make necessary improvements based on their experiences.
- m) **Public Awareness and Transparency:** Communicate the benefits of the ICJS to the public, emphasizing its role in improving the efficiency and effectiveness of the criminal justice system. Address concerns about data security and privacy.
- n) **Evaluation and Adaptation:** Regularly evaluate the ICJS's effectiveness in achieving its goals and adapt the system based on changing needs and technological advancements.

5. Policy Recommendations

- a) Biochemical markers need to be designed regarding regional, occupational and geographical locations regarding non-invasive methods of exoskeleton, hair, teeth, bones for fast and reliable identification.
- b) Implementation of standardized advanced methods for the human identification in addition to modification of the existing methods.
- c) Policies should be established and maintained of centralized databases, emphasizing data security, privacy, and international cooperation for cross-border data sharing which will be beneficial in human identification during a mass disaster.
- d) Standardized policies and guidelines should be made regarding humanitarian aspects of human identification.
- e) Standardized policies and guidelines should be made regarding crime against child & women, illegal migration, sexual abuse cases.
- f) Recommendation of guidelines for quality assurance, ensuring consistency and reliability across different laboratories.
- g) Improving funding for research and development, enabling the adoption of cutting-edge technologies and methodologies.
- h) Advocate for collaboration between forensic scientists, medical experts, legal experts, and policymakers to develop comprehensive strategies.



6. Capacity Building and Training

Infrastructural Development- Investment in state-of-the-art laboratory infrastructure, including equipment, facilities, and IT systems. Introduction of exclusive infrastructure of Mass Fatality Response Unit and Veterinary Forensic Unit at National Forensic Sciences University. Veterinary forensics is not only providing solutions for the complexities for the identification of the species among the carcasses but also provides solutions for the questions on the authenticity of the animals attack for the purpose of the proper compensations those are being claimed by the victims. (death due to snake bites and wild animals attack are compensated by the respective governments).

Workforce Development: Propose initiatives for training forensic personnel in the latest techniques, ensuring a skilled workforce capable of handling advanced technologies in a more comprehensive manner.

7. International Cooperation

Establishment of international standards, data sharing, and collaboration to facilitate seamless cooperation across borders.

Collaboration with the needy governments across the globe may enhance the dissemination of the knowledge and skills by way of collective efforts wherever it is relevant.

Conclusion

In the realm of medicolegal investigations, human identification stands as a fundamental and multifaceted challenge, where science and justice converge to provide answers to the most complex questions. Human identification, whether in cases of mass disasters, criminal investigations, or missing persons, is not merely about solving puzzles but about bringing closure, justice, and peace to those affected by tragedy. It embodies the relentless pursuit of truth, compassion, and the unwavering commitment to upholding the dignity of every individual. As technology continues to advance, medicolegal investigations into human identification will remain a vital and evolving discipline, offering hope and answers to those in search of them.



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Chapter 9

Advanced Fingerprinting Techniques in Criminal and Routine Personal Identification : A Non- Invasive Approach

Dr. G. Rajesh Babu¹

Introduction

Fingerprints is one of the most conventional methods of criminal identification. Fingerprints though has been in application for more than a century, it still rules the roost as far as personal identification is concerned. Fingerprints is more robust, non-duplicating and more reliable for the criminal investigation and identification of criminals. Its reliability and the robustness have been employed in the authentic tool of personal identification. Numerous studies have been conducted on the human population within the realm of dermatoglyphics, a field focused on the study of fingerprints, palm prints, and sole prints. Fingerprints are a vital form of evidence within the field of forensic science, serving as a unique and invaluable tool for criminal investigations and legal proceedings. The distinct ridge patterns present on the friction ridges of human fingers and palms offer a reliable and authentic information that can be applied to establish identity, connect individuals to crime scenes, and contribute to solving a wide array of criminal cases. Since the advent of fingerprints in personal identification with the pioneering work of Sir Francis Galton, Edward Henry and Juan Vucetich fingerprint analysis has been found to be more consistent with the powdering methods. The methodology has also been maintained with the simplistic and result oriented. Fingerprints are being contemplated for the comprehensive individual profiling.

Current Landscape of Fingerprint Sciences

The existing fingerprint technology has predominantly been developed with the

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main focus on attributes at the first and second levels. It is widely acknowledged that the success of fingerprint recognition relies on the presence of 8-12 minutiae, with the specific number varies across different countries. However, relying solely on patterns and minutiae points may not always yield good results when processing fingerprints. The primary factor is the frequent occurrence of fragmented or distorted fingerprints at crime scenes. Due to their lack of distinguishing features, these defective fingerprints may not match those already stored in a database, reducing their usefulness for identification purposes. The landscape of fingerprint sciences has evolved dramatically in recent years, driven by advances in technology, research, and an ever-expanding range of applications.

1. **Automated Fingerprint Identification Systems (AFIS):** One of the most transformative advancements in fingerprint science is the development and widespread implementation of AFIS. The Automated Fingerprint Identification System (AFIS) is a biometric identification technique that use digital imaging technology for the acquisition, storage, and analysis of fingerprint data. The AFIS database is capable of storing a substantial number of fingerprint images, reaching into tens of millions. The database employs an algorithm to identify the most probable matches for the newly introduced print, hence reducing the scope of the search for investigators. The conclusive examination of the print and the retrieved images is conducted by AFIS Technicians in order to ascertain the precision of identification. The computer is able to do a task in a matter of minutes that would have previously required several weeks to accomplish prior to the implementation of computerization within the system. The Automated Fingerprint Identification System (AFIS) was initially employed by the Federal Bureau of Investigation (FBI) of the United States for the purpose of criminal investigations. These computer-based systems can rapidly search and match fingerprint records from vast databases, greatly expediting the identification process. Modern AFIS can handle millions of prints, enabling law enforcement agencies to solve cases more efficiently.

National Automated Fingerprint Identification System (NAFIS): The National Automated Fingerprint Identification System (NAFIS) is a system that has been established by the National Crime Records Bureau (NCRB) at the Central Fingerprint Bureau (CFPB) located in New Delhi. The proposed initiative includes the development of a comprehensive, nationwide database that enables the efficient search and retrieval of fingerprints associated with illegal activities and individuals involved in criminal behaviour. The web-

based tool serves as a centralized repository of information by aggregating fingerprint data from all states and Union Territories. Law enforcement agencies are provided with the capability to upload, track, and access data from the database in real-time, operating continuously on a 24x7 basis. The National Automated Fingerprint Identification System (NAFIS) is responsible for allocating a distinct 10-digit identifier known as the National Fingerprint Number (NFN) to individuals who have been apprehended for criminal activities. The assigned unique identifier will have a lifelong application, facilitating the linkage of many criminal offenses recorded in separate First Information Reports (FIRs) to a singular National Forensic Number (NFN). The inclusion of this information in the CCTNS (Crime and Criminal Tracking Network & Systems) database is facilitated by their interconnectedness at the backend. The automation of the fingerprint database was initiated by the Central Fingerprint Bureau in 1986, following the proposals put forth by the National Police Commission. The process was initiated by the digitization of the pre-existing manual records in 1992, with the introduction of India's inaugural Automated Fingerprint Identification System (AFI), known as the Fingerprint Analysis & Criminal Tracing System (FACTS 1.0). According to a report published by the National Crime Records Bureau (NCRB) in 2018, the most recent version of the system, FACTS 5.0, which underwent an upgrade in 2007, was deemed to have exceeded its expected lifespan. Consequently, the report recommended its replacement with the National Automated Fingerprint Identification System (NAFIS).

2. **Biometrics and Security:** Fingerprint biometrics can serve as a means of person authentication by comparing the data stored in a system, or it can function as a mechanism for identity verification to establish the veracity of an individual's claimed identification. The utilization of fingerprint biometrics can enhance the level of security beyond traditional password and token security procedures. Fingerprint sensors are widely utilized in contemporary electronic devices such as smartphones, computers, and other similar gadgets to ensure enhanced security measures. Furthermore, this technology has been utilized in other domains such as passport control, national identification programs, and the establishment of secure access to structures.
3. **Latent Print Development:** Significant advancements have been made in the field of latent print development, particularly in the area of revealing prints that are not readily observable. Methods such as cyanoacrylate (commonly known as super glue) fuming, ninhydrin, and small particle chemicals have demonstrated enhanced efficacy and increased dependability. These

techniques facilitate the retrieval and visualization of latent fingerprints from a wider array of surfaces and substrates, encompassing difficult and porous substrates.

4. **Enhanced Imaging Technology:** Recent advancements in imaging technology and three-dimensional (3D) scanning techniques have significantly improved the capacity to collect and analyze detailed ridge patterns and minutiae. High-resolution optical and laser scanners offer enhanced levels of detail, hence enabling more accurate comparisons and identifications. Furthermore, the utilization of 3D scanning techniques enables the thorough analysis of the surface characteristics of fingerprint ridges, hence potentially revealing other unique features. The multispectral imaging device captures images at multiple wavelengths across the electromagnetic spectrum, including visible, ultraviolet, and infrared wavelengths. This enables forensic experts to see details that might be invisible to the naked eye or traditional imaging systems.
5. **Ridge Morphometric and Morphological Analysis:** Ridgeology is one of the new techniques used for personal identification and it is the study of the individuality of friction ridge structures. A fingerprint is made up of series of ridges and valleys present on the surface of the finger. The uniqueness of a fingerprint can be determined by the pattern of ridges and valleys as well as the minutiae. It includes the study of minute details like ridge ends, bifurcations, enclosures, and dots as well as macroscopic features like ridge flows and patterns. Ridgeology recognizes that each person's friction ridge skin is a complex surface with unique patterns created by genetic and physiological processes. Ridge thickness, Ridge Density, Ridge Count are the different parameters to be studied under the Ridge Morphometric analysis for identification. Ridge thickness refers to the width of the ridges that make up the patterns on a fingerprint. The ridge thickness can vary across different individuals and even within the same fingerprint. During the formation of ridges on the fingertips, the ridge thickness is influenced by various factors, including genetic factors, environmental factors, and the growth process of the skin. These factors contribute to the unique and individualistic nature of fingerprints. Ridge density refers to the number of ridges present within a specific area of a fingerprint. When examining ridge density, forensic experts focus on a particular region of interest within a fingerprint, such as a square or rectangular area. They count the number of ridges present within that area and calculate the ridge density by dividing the ridge count by the area size. The ridge density can vary between individuals and even within different areas of the same fingerprint. It is observed in various studies that women tend to have high ridge density, where the ridges are closely packed together, while men may have lower ridge density, with more space between

the ridges. The ridge count refers to the quantity of ridges that are present between the delta and the core. Every ridge that touches or makes contact with an imaginary path extending from the delta to the core. Both delta and core are not included in the count.

6. **Pore Morphometric Analysis:** Poroscopy is a scientific methodology that entails the examination and evaluation of the spatial arrangement, dimensions, morphology, and attributes of pores present in the epidermal ridges of friction skin. Pores are little natural apertures situated inside the dermal ridges of the fingertips and hands. Poroscopy is a somewhat obscure method in the field of forensic science; yet, it possesses the potential to serve as a supplementary means for personal identification, particularly in situations when conventional ridge patterns may be warped or provide challenges in analysis.
7. **Molecular Fingerprinting:** Molecular fingerprints refer to the presence of residual molecules from the components detected in fingerprints. The presence of certain elements in fingerprints may exhibit excessively high levels. The molecular composition of fingerprint residue primarily consists of the metabolic by-products resulting from the physiological processes occurring within the human body. This analysis aims to determine the potential identification of compounds or minerals that an individual may have consumed, swallowed, inhaled, or been exposed to in their surroundings as a result of their dietary habits and occupational activities. The presence of components in fingerprint residue is influenced by various factors such as geographical location, habits, occupation, and lifestyle. For instance, the presence of certain chemicals may contribute to the establishment of specific habits, such as Narcotine abuse, nicotine addiction, and chewing tobacco consumption. Molecular fingerprinting can play a crucial role in narrowing down the pool of potential suspects or matches. Incorporating molecular fingerprinting into the fingerprint analysis system can revolutionize the field of forensics by overcoming the limitations posed by powder and chemical methods. By providing accurate and reliable identification even in challenging scenarios, this approach enhances the efficiency and accuracy of criminal investigations, potentially leading to quicker resolutions and reduced miscarriages of justice.

Key Technological Advancements

Instrument/ Tool/ Technique	Application
AFIS	Automated fingerprint identification system is the process of using a computer to match fingerprints against a database of

Instrument/ Tool/ Technique	Application
	<p>known and unknown prints in the fingerprint identification system.</p> <p>AFIS are primarily used by law enforcement agencies for criminal identification purposes, the most important of which is the identification of a person suspected of committing a crime or linking a suspect to other unsolved crimes.</p> <p>IAFIS (Integrated Automated Fingerprint Identification System) is an AFIS, which was developed and maintained by the FBI in 1999.</p>
NAFIS	<ol style="list-style-type: none"> i. It assigns a unique 10-digit National Fingerprint Number for each criminal, based on biometrics. ii. This 10-digit ID will be used for an individual's lifetime, and different crimes registered under different FIRs will be linked to the same National Fingerprint Number. iii. It enables law enforcement agencies to upload, trace, and retrieve data from the database in real time on a 24×7 basis.
Comparison Microscope	<ol style="list-style-type: none"> i. This facilitates the comparison of latent (crime scene) prints with known prints. ii. Comparison microscopes are essential in determining whether two prints match. iii. It is used in questioned document examination for the comparison of ink various marks present on the document. iv. It is used for the split image comparison of currency notes or bank notes. v. It can also be used to compare paint chips, glass fragments, soil particles, etc.
Forenscope 4K	<ol style="list-style-type: none"> i. The Forenscope 4K employs multispectral imaging, which means it captures images at multiple wavelengths across the electromagnetic spectrum, including visible, ultraviolet, and infrared wavelengths. ii. It can reveal latent prints on a variety of surfaces, even on challenging or porous surfaces. iii. Different wavelengths can reveal different types of evidence, such as bloodstains, bruises, and fingerprints.



Instrument/ Tool/ Technique	Application
	iv. It can be used for post-mortem examinations and documentation of injuries or trauma on deceased individuals.
Stereo Microscope	i. Its wide field of view and great depth focus makes it ideal for examination of sweat pores. ii. To visualize minute details with pores and ridge edges helps in 3rd level identification. iii. Its annotation features aid in morphometric analysis of fingerprint ridges as well as pores dimensions.
Electrostatic Dust Finger print Lifter	Using high voltage electrostatic charges, lifts dust fingerprints from surface to a black plastic film from better contrast and photography.
Live Fingerprint Scanners	i. These high-resolution scanners capture digital images of fingerprint impressions. ii. They are used for creating digital databases of known fingerprints, as well as for recording latent prints from crime scenes. iii. Laser scanners use lasers to create 3D representations of fingerprint ridges. iv. They can capture the topography of ridge patterns and minutiae, offering additional information for analysis.
Reflected Ultra Violet Imaging System (RUVIS)	i. It provides more sensitive enhancement methods than traditional. ii. It enables to collect the prints from surfaces like plastic bags, sticky tapes, glossy surfaces, magazines, photographs, linoleum tiles, compact discs, credit cards, etc.
AAS	i. Mainly used for biochemical analysis of fingerprint residue. ii. Detection of trace elements present in fingerprint residue.

Instrument/ Tool/ Technique	Application
ProScope- USB Handheld Microscope	i. ProScope USB microscopes typically offer high-resolution imaging capabilities, allowing forensic experts to capture clear and detailed images of fingerprint impressions. ii. This level of details is crucial for the accurate analysis of ridge patterns, minutiae, and other fingerprint characteristics. iii. They assist forensic experts in the examination of evidence, such as fingerprint ridges, pores, handwriting, hair, fibres, physical and ballistic evidences.
XRF(EDXRF, WDXRF)	i. The identification of trace elements present in fingerprint residues can be achieved using this technique. ii. It is beneficial in the analysis of rocks, soils and other similar substances, allowing the analyst to compare the composition of these samples. iii. The technique can be used in the detection of counterfeit coins.
	iv. Inks and paints are particularly suitable for analysis by XRF techniques, as they typically contain metallic pigments which can differ wildly between different brands and batches.
XRD	i. Building materials such as cement, concrete, steel rods, bricks, etc. ii. Residues from site of arson such as kerosene oil, gasoline or cotton lints. iii. Explosive residues and splinters from sites. iv. Accident scene samples such as blood spots, paint chips, etc. v. Assault samples such as torn garments, broken glass, cosmetic marks, semen stains, etc. vi. Theft and robbery site samples which include gunshot residues, tools, murder weapons, forged documents, blood residues, etc.
NAA	i. Biochemical Elemental Analysis ii. Soil Analysis iii. Hair and nail examination.



Instrument/ Tool/ Technique	Application
SEM	<ol style="list-style-type: none">i. Fingerprint residue analysisii. Handwriting and print examination / forgeryiii. Investigation of gemstones and jewelleryiv. Examination of paint particles and fibresv. Filament bulb investigations at traffic accidentsvi. Counterfeit bank notesvii. Trace comparisonviii. Examination of non-conducting materialsix. High resolution surface imaging
TEM	<ol style="list-style-type: none">i. TEM can be very useful in forensic trace evidence analysis.ii. Used to analyze the morphology of fingerprint residues.iii. elemental information on very small particles and determine the internal structure of small particles.
AFM	<ol style="list-style-type: none">i. To study the surface morphology and topography of the various specimens like fingerprint ridges, pores, biological samples.ii. Used in GSR, explosives, and physical analysis of evidence.iii. Beneficial in computational and document analysis.
Raman Spectroscopy	<ol style="list-style-type: none">i. to study molecular structure of different compounds present in fingerprint residues.
SEM EDX	<ol style="list-style-type: none">i. SEM can magnify any object 2, 00,000 times as magnifying power of 1000 times of a conventional microscope. SEM is useful to study the morphological, surface characteristics by scanning the surface of any tiny sample such as pollen, gun shot residue, dust, fibres, hair, tool marks, fingerprint residue.ii. The built - in computer has the capacity to store a large number of micrographs of samples for reference and subsequent comparison.iii. The elemental composition of the sample can be instantly checked with X-ray Micro-analyzer simultaneously.

Instrument/ Tool/ Technique	Application
Inductively coupled plasma with Mass Spectrometer (ICPMS)	<p>ICPMS is an analytical technique used for elemental analysis. It combines the capabilities of inductively coupled plasma (ICP) and mass spectrometry to determine the elemental composition and isotopic ratios of a wide range of samples like fingerprint residues, sweat, ink, gun shot residues, soil, water, etc.</p> <p>Analysis of rock samples for mineral exploration, detection and quantification of trace elements in drugs, analysis of heavy metals and contaminants in food and beverages. Forensic identification of trace elements.</p>

Policy Recommendations

Data Management and sharing - Considering many countries, including Interpol, keep their fingerprint databases in NIST format, NAFIS is likewise constructed to NIST standards. Andhra Pradesh, Karnataka, Kerala, Maharashtra, and Telangana are among the states that have recently implemented the link software is being used to preserve their investment in a NIST approved AFIS system. All of these states, however, will be making NCRB-provided equipment was used to conduct countrywide searches. NAFIS and CCTNS are being connected for demographic data interchange. Because demographic information is recorded into CCTNS when a criminal is apprehended or convicted, Such details do not need to be re-entered by FP experts; instead, they will be copied. entering NAFIS.

In addition to NAFIS, a database can be created for ridgeology, poroscopy and molecular fingerprinting for the profiling of the individuals which will be helpful for narrowing down the vast searches of the suspect by analyzing the parameters like geographical locations, occupation, lifestyles, and habits of the individuals. Thereby it becomes a marker for the demographic, geographic and occupational traits.

Inclusion of advanced techniques in system: There is need for the inclusion of molecular fingerprinting in the donor profiling by the use of biochemical analysis of fingerprint residues. It will help in identifying the geographical location, occupations, habits and lifestyle of the individual. This includes the non-destructive methods of development and documentations and further analysis based on the chemical and biochemical aspects.

Quality Control and Standardization- Procedures and processes in forensic practice need to be a blend of expertise, experience, excellence and advancement, to render quality service and garner global credibility. To enable efficient data sharing, law enforcement agencies must adhere to common data standards and interoperability protocols. These standards ensure that fingerprint data from various agencies and jurisdictions can be easily exchanged and compared, regardless of the system or software used. Therefore, the following are recommended.

- a) There should be discipline wise Scientific Task Forces (STFs) in the lines of Technical Working Groups (TWG) / Scientific Working Groups (SWG), to deliberate and bring out Standard Operating Procedures (SOP) / Manuals. Such exercise should naturally take care of application of recent S & T developments in evidence search / location/ collection / analysis and court testimony; for example: kits, robots, high – throughputs, automation, video conferencing. STFs should also review and revise such documents (already in use as well as those forthcoming for new and emerging areas) every three years, so that Good Laboratory Practice (GLP) prevails.
- b) There should be mandatory Certification (and quadrennial Recertification) of forensic professionals.
- c) Regularly validate and verify fingerprint analysis techniques and procedures. Conduct proficiency testing for analysts to ensure their competence and adherence to established standards.
- d) Every forensic laboratory should be accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL) accompanied by the stipulated upkeep and surveillance.

Research and Development Funding - Research is founded on aptitude, focus, sacrifice and perseverance; then come motivation, incentives and awards. Researching should be a passion and a habit. Recommendations for reorienting forensic R & D are as follows.

- a) Encouragement should be given to every forensic scientist (and team) to pursue case work hyphenated R & D, intramural innovative R &D and Ph D – guiding R & D; such researchers should also bring in R & D project money from outside through international and national funding agencies.
- b) Cash awards should be introduced on every publication in international journal by the scholars.



- c) Exclusive budget provision for foreign travel should be earmarked to enable its employees and research fellows chair sessions, deliver talks and present research papers at scientific meetings.
- d) Exclusive researches could be encouraged with the funding through the central agencies for the work on the personal identification based on the gender and age determinants based on the fingerprint residues

Interdisciplinary Collaboration –There should be measures to increase the level of awareness among stakeholders (judiciary, police etc)

- a) Awareness courses on the modern techniques and on the fingerprints analyses at NFSU for the CFSLs, judicial academies, police academies, directorates of prosecution and bar council
- b) Forensic experts /fingerprints scientists’ participation in Zonal, State and National Police Duty Meets
- c) Regular mailing of (CFSLs’ in-house) Newsletters to the forensic customers
- d) Inviting their scripts for inclusion in such Newsletters with a focus on chemical and biological researchers and academicians
- e) Inviting their informal participation in CFSLs’ Monthly Journal Club Meetings for the periodical updates on the current scenario and the issues faced by them
- f) Vibrant deliberations at meetings of the CFSLs’ Forensic Stakeholders’ Consultative Committees
- g) All the Central forensic establishments have been accredited by NABL; State / UT forensic establishments should also fall in line immediately.

Capacity Building And Training

The variety of training/ refresher courses will be imparted to police officers, stake holders, judicial officers, investigating officers and staff of Fingerprint bureaus from India and other countries regarding advanced technologies as well as molecular fingerprinting identification. Indian law enforcement and forensic experts participate in international workshops, seminars, and training sessions to stay updated on emerging trends and techniques in crime investigation and forensic analysis.

International Cooperation

International cooperation often involves training programs and capacity-building initiatives. In cases relating to international crimes or individuals with



international connections, law enforcement agencies collaborate on fingerprint data sharing at the international level so that any kind of prints from anywhere, we will be available to share the data and identify the prints. Interpol, for instance, facilitates the exchange of fingerprint and biometric data among member countries to combat cross-border criminal activities.

Conclusion

The identification of fingerprints or chance prints at a crime scene represents an essential moment in the field of forensic investigations. The unintentional existence of these prints can serve as a significant form of evidence. Nevertheless, it is essential to ensure the preservation and analysis of these prints without causing any harm or modification. The extraction, preservation, and comprehensive analysis of fingerprints have been made possible by recent breakthroughs in forensic science and technology, hence presenting novel opportunities for investigative purposes. Forensic professionals utilize sophisticated imaging technologies and specialized illumination devices to non-invasively retrieve fingerprints from diverse surfaces. The aforementioned procedures have been developed with the objective of mitigating any potential harm to the printed material, while simultaneously guaranteeing its perceptibility and preservation. These systems employ several wavelengths, such as visible, ultraviolet, and infrared, to collect photos of the prints, thereby augmenting the distinction between the print and its background. After the fingerprint has been retrieved and maintained without causing damage, forensic professionals have the ability to do biochemical analysis on the residues that were left behind by the individual who donated the fingerprint. Fingerprint residues frequently comprise a diverse array of substances, encompassing amino acids, proteins, and lipids. Through the analysis of these substances, it is feasible to acquire valuable insights regarding the identity of the individual responsible for leaving the print. Fingerprint analysis extends beyond the mere identification of the donor. In addition to their primary responsibilities, forensic scientists are also involved in the establishment and maintenance of a comprehensive database containing ridge morphometric characteristics and pore morphometric information. The process entails the measurement and quantification of diverse characteristics present in the fingerprint, including ridge density, ridge count, ridge breadth, pore location, and pore size. The integration of ridge and pore morphometric features with biochemical analysis data constitutes a robust methodology for the discernment of people. The uniqueness of each individual's fingerprint and the

utilization of these characteristics can build a highly particular profile for an individual.

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Chapter 10

Best Practices in Cyber and Digital Crime Investigation

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Introduction

Advanced forensics, network security, visual and reliability studies, and other fields are continually developing in today's networked computer world to handle the growing issues posed by cybercrime, data disruption, and the explosion of media material. These topics are covered in this chapter, along with some of the more recent trends that contributed to this turn of events. Advanced tools, structures, and frameworks for study and investigation are used in computer-based criminology to compile evidence for legal uses. It is a vital aspect of combating cybercrime, identifying data breaches, and guaranteeing the integrity of digital evidence. Computational forensics, versatile forensics, cloud-based crime scene investigations, Internet of Things legal criminology, computer intelligence crime scene investigations, military forensics, coded device crime scene investigations, abuse battles, vehicle and theatre task criminology, drone forensic doctors, and more are the most recent models of advanced criminology. The Media Act addresses the analysis and verification of audio and visual content, including photographs, videos, and sound recordings. The credibility and integrity of the developed media are essentially protected by this sector. The

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most recent models of vision and legal investigations include mixed blockchain, audio and video content validation, thorough forgery detection, support investigation, and criminology of virtual entertainment material. Protecting high-level frameworks, organisations, and data against unauthorised access, threats, and vulnerabilities is the main goal of digital security. It is a crucial component of today's computerised infrastructure. Zero Trust Design, modernised AI threat detection, ransomware insurance, quantum-secure encryption, product network protection, and other methods are now used for network security. When it comes to information assurance, cybercrime investigations, and maintaining the credibility of electronic media, experts in these sectors must constantly adapt to new difficulties and technological advancements.

Current Landscape of Digital Forensics, Multimedia Forensics and Cyber Security

In today's rapidly evolving technological landscape, the fields of digital forensics, multimedia forensics, and cybersecurity have become more critical than ever. This chapter provides an overview of the current state of these interconnected domains.

Digital Forensics

Evaluation of Digital Forensics

Digital forensics, also known as computer forensics, has evolved significantly to address the growing complexity of digital devices and data storage.

In the current landscape following evaluation trends may be considered:

Computer Forensics: Computer forensics involves the examination of computers, laptops, and servers to gather evidence related to cybercrimes or other digital incidents. This may include recovering deleted files, analyzing hard drive data, and tracking internet activity.

Mobile Device Forensics: Mobile device forensics deals with smartphones, tablets, and other portable devices. Investigators extract and analyze data from these devices, including call logs, text messages, GPS information, and app data.

Cyber (Network) Forensics: Network forensics focuses on monitoring and analyzing network traffic to detect and investigate security incidents. It aids in the detection of network abnormalities, data breaches, and unauthorized access.



Memory Forensics: RAM, or volatile memory, is examined as part of memory forensics. Memory dumps are analyzed by investigators to find active programmes, malware, and other potential non-disk evidence of malicious activity.

Email forensics: Examining email conversations and attachments is the focus of email forensics. It is frequently used to identify the origin of spam, phishing scams, and other email-related crimes.

Database Forensics: In order to find proof of data breaches, unauthorised access, or data modification, database forensics analyse databases and data storage systems.

Cloud Forensics: Investigation of data stored in cloud services like Dropbox, Google Drive, or AWS is known as “cloud forensics.” It tackles the issues of data ownership, jurisdiction, and access to cloud-based evidence.

IoT (Internet of Things) Forensics: Investigating linked devices in smart homes, wearable technology, and industrial IoT systems is the focus of IoT forensics. It seeks to find digital evidence pertaining to IoT security events and breaches.

Social Media Forensics: Cyberbullying, harassment, online threats, and other crimes using social media are the subject of social media forensics, which analyses social media platforms to obtain digital evidence.

Automotive Forensics: Digital investigations involving contemporary cars are the focus of automotive forensics. To rebuild accidents or evaluate vehicle tampering, it involves analyzing in-car systems, infotainment systems, and event data recorders (EDRs).

Malware analysis: It is the process of analyzing harmful software to learn about its features, causes, and effects. It aids in the detection and reduction of cybersecurity risks.

Forensic Data Analytics: Data analysis methods are used in forensic data analytics to find trends, abnormalities, and fraud in digital data. It is frequently applied to fraud detection and financial investigation.

Virtual Machine (VM) Forensics: In the field of virtual machine forensics, virtualized environments are the focus. To find information about cybercrimes or other occurrences that occurred within virtualized infrastructure, investigators examine virtual machine snapshots or containers.

Industrial Control System (ICS) Forensics: ICS forensics is a branch of computer science that focuses on the security and forensic examination of industrial control systems, such as those employed in vital infrastructure industries like manufacturing, transportation, and energy.

Diversity in the Devices: In the current era of the technological advancements the variety of devices are available in the use for the people, which includes smartphones, IoT devices, cloud services, and even automobiles with integrated computers, are now included in the scope of digital forensics.

Encryption Challenges: As technology has developed, gadgets that are now on the market have greater security features, including a rise in the usage of device- and file-based encryption. This makes it more difficult for investigators to access data on devices, which has raised debate over the trade-off between privacy and security.

Current challenges in digital forensics

The digital forensics domain faces several challenges as under.

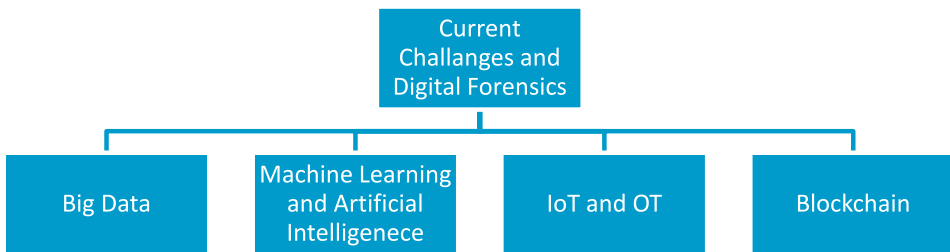


Fig. 1.1 Current Challenges in Digital Forensics

Big Data: The sheer amount of data that is produced every day creates difficulties for storage, processing, and analysis.

Machine learning and artificial intelligence: ML and AI are rapidly being used to automate the processing of digital evidence, improving the effectiveness of investigations.

Internet of Things (IoT) and OT: As IoT devices proliferate, there is a greater opportunity to collect digital evidence from linked cars, smart homes, and wearables. The majority of critical infrastructure makes use of operational technology (OT), while most of the critical infrastructure built during the 20th century has not been replaced over time and continues using outdated technology.

However, as these outdated technologies are connected to more recent ones, concerns have been raised about the security of these critical infrastructures.

Blockchain: Investigating crimes involving cryptocurrencies and blockchain technology requires specialized knowledge and tools.

Multimedia Forensics

Scope of Multimedia Forensics

Multimedia forensics focuses on the analysis of multimedia data, including images, audio, and video. It plays a vital role in various areas:

Image and Video Authentication: Determining the authenticity of images and videos by detecting tampering or manipulation.

Voice and Speaker Recognition: Identifying speakers or verifying the authenticity of audio recordings.

Steganography Detection: Detecting hidden information within multimedia files.

Deepfake Detection: As deepfake technology advances, multimedia forensics experts are developing sophisticated tools to detect manipulated videos and images to prevent misinformation and fraud.

Image Forensics for social media: Given the prevalence of social media and the spread of fake news, image forensics tools are being used to identify and verify the origins of images shared online.

Blockchain for Media Authentication: Some initiatives are exploring the use of blockchain technology to create immutable records of media content, ensuring its authenticity and source attribution.

Current Challenges in Multimedia Forensics

Multimedia forensics faces unique challenges are as under:

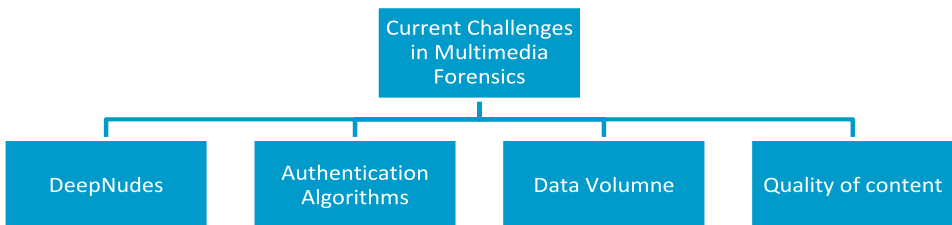


Fig. 1.2 Current Challenges in Multimedia Forensics

DeepNudes: The rise of deepfake technology poses significant threats, as AI-generated pornographic content can be convincingly manipulated.

Authentication Algorithms: The development of robust algorithms for authentication and tampering detection is an ongoing challenge.

Data Volume: The proliferation of multimedia content on social media and the internet increases the volume of data that forensic analysts must examine.

Quality of content: The quality of multimedia content plays a major challenge in the investigation of any individual or the object.

Cybersecurity

The Cybersecurity Landscape

Cybersecurity is a critical concern for individuals, businesses, and governments:

Cyberattacks: The frequency and sophistication of cyberattacks continue to rise. Threat actors employ tactics such as ransomware, phishing, and advanced persistent threats (APTs).

IoT Vulnerabilities: The growing number of IoT devices introduces new security vulnerabilities, as many lack adequate protection.

Regulations: Data protection regulations, such as GDPR and CCPA, have imposed stricter requirements on organizations for safeguarding customer data.

Emerging Trends in cyber security

Cybersecurity is adapting to address emerging threats are as under:

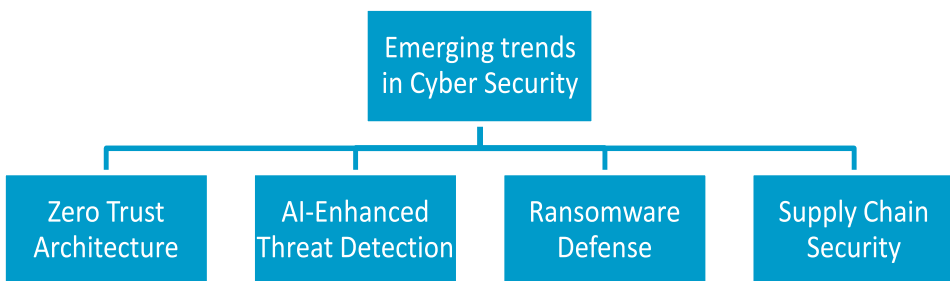


Fig 1.3 Emerging Trends in Cyber Security

Zero Trust Architecture: This security model assumes that threats may exist inside and outside the network. It requires continuous verification of users and devices, even if they are already inside the network.



AI-Enhanced Threat Detection: Leveraging artificial intelligence and machine learning, cybersecurity solutions can identify and respond to threats in real time by analyzing patterns and anomalies.

Ransomware Defense: As ransomware attacks increase in sophistication, organizations are adopting advanced techniques like data backups, network segmentation, and employee training to defend against them.

Supply Chain Security: Cybersecurity is now extending to the supply chain to ensure that third-party vendors and software components do not introduce vulnerabilities into an organization's systems.

Interconnectedness of the Fields

Digital forensics, multimedia forensics, and cybersecurity are interconnected in various ways:

Evidence Handling: Digital and multimedia forensics provide crucial evidence in cybersecurity investigations.

Threat Detection: Cybersecurity measures help protect digital and multimedia forensic data from unauthorized access.

Training and Knowledge Sharing: Professionals in these fields often collaborate and share knowledge to stay ahead of evolving threats.

Technological advancements in cybersecurity, digital forensics, and multimedia forensics

Technological advancements in cybersecurity, digital forensics, and multimedia forensics play a critical role in staying ahead of evolving cyber threats, ensuring data integrity, and verifying the authenticity of digital media.

Cybersecurity-related technological advancements

AI and Machine Learning: AI-driven cybersecurity solutions can detect and respond to threats in real time by analysing vast datasets to identify patterns and anomalies, making them more effective at threat mitigation.

Behavioural Analytics: Advanced behavioural analytics systems use machine learning to establish a baseline of normal behaviour for users and devices, allowing them to detect unusual or suspicious activities indicative of cyberattacks.

Zero Trust Architecture: Zero Trust models, which assume that threats may exist both inside and outside the network, are gaining popularity. They require continuous verification of users and devices, reducing the attack surface.

Quantum-Safe Cryptography: As quantum computing threatens current encryption algorithms, the development of quantum-safe cryptography ensures that future cybersecurity measures remain resilient to quantum attacks.

Deception Technologies: Deception-based cybersecurity solutions create fake assets, data, or network resources to mislead attackers and detect their presence early in the attack lifecycle.

Container Security: With the increasing adoption of containerization and microservices, container security solutions provide protection for containerized applications and workloads.

Digital Forensics related technological advancements

Memory Forensics: Advances in memory forensics enable investigators to analyze volatile memory (RAM) for signs of malicious activity and gain insight into processes running on a system.

Cloud Forensics: Specialized tools and techniques have emerged for investigating data stored in cloud services, addressing challenges related to jurisdiction, data ownership, and access.

Machine Learning in Forensics: Machine learning algorithms are used to automate the analysis of digital evidence, speeding up investigations and improving accuracy.

Blockchain Forensics: As cryptocurrencies and blockchain technology continue to grow, blockchain forensics tools help trace transactions and uncover illicit activities on blockchain networks.

Artificial Intelligence in Forensics: AI is used to sift through vast datasets, recognize patterns, and identify digital evidence more efficiently, aiding in the investigation process.

Live Forensics: Live forensics techniques allow investigators to gather digital evidence from active, running systems without disrupting their operation.

Automated Data Recovery: Advanced data recovery tools can reconstruct fragmented or deleted data from storage media, helping recover valuable evidence.



Multimedia Forensics related technological advancements

Deepfake Detection: AI-powered deepfake detection tools use facial recognition, voice analysis, and image forensics to identify manipulated videos and images.

Image and Video Analysis Algorithms: Advanced algorithms can analyze images and videos to detect inconsistencies, alterations, or hidden information, aiding in media authentication.

Blockchain for Media Authentication: Blockchain technology is used to create immutable records of multimedia content, ensuring its authenticity and source attribution.

Audio Authentication: Advanced audio forensics tools can verify the authenticity of audio recordings by analyzing characteristics like voiceprints and noise patterns.

Social Media Image Analysis: Tools and techniques for social media image forensics help verify the origins and authenticity of images shared on social platforms.

Steganalysis: Steganalysis techniques have evolved to detect hidden information within digital media, including text, images, and audio.

Policy Recommendations on Digital Forensics, Multimedia Forensics and Cyber Security

Policy recommendations for Digital Forensics

To guarantee that investigation procedures and the application of technology respect people's rights and freedoms, policy guidelines for human rights in digital forensics are crucial.

Here are some crucial suggestions for policy in this regard:

Regulatory Environment and Compliance

Establish a thorough legal framework that expressly states how people are entitled to their rights during digital forensics investigations.

Ensure that all digital forensics procedures, including data gathering, processing, and storage, adhere to all applicable laws and norms pertaining to human rights.

Warrant Requirement

Implement severe procedures for obtaining digital search warrants, such as proving probable cause and specificity in the scope of the search.

Ensure that digital evidence gathered without a legitimate warrant is inadmissible in court proceedings.

Data Minimization and Retention Limits

Enforce data minimization rules, where only relevant and essential data should be acquired during investigations.

Establish explicit guidelines for the keeping of digital evidence and consider restricting the retention duration to avoid unwarranted data retention.

Transparency and Accountability

Increase openness in digital forensics operations by forcing investigators to thoroughly record their techniques and results.

Create procedures for supervision and responsibility to ensure that investigators follow ethical and legal guidelines.

Access to Legal Counsel

To protect their rights and interests, ensure that persons under investigation have access to legal representation throughout the digital forensics process.

Informed Consent

When feasible, get informed consent for the gathering and processing of digital evidence, especially if the individual is not a suspect.

Data Protection and Encryption

Recognize the importance of strong data protection and encryption measures. Encourage the responsible use of encryption technologies and avoid policies that undermine individuals' security and privacy.

Protection of Vulnerable Populations

Implement additional safeguards to protect the rights of vulnerable populations, such as minors, victims, and marginalized communities, during digital forensics investigations.



Cross-Border Data Sharing

Establish protocols for cross-border data sharing in digital forensics investigations, ensuring that data shared between countries is subject to equivalent human rights protections.

Ethical Guidelines and Training

Develop and promote ethical guidelines for digital forensics professionals, emphasizing the importance of respecting human rights in their work.

Mandate training and certification programs for digital forensic investigators to ensure they are knowledgeable about human rights principles and best practices.

Public Awareness and Education

Conduct public awareness campaigns and educational initiatives to inform citizens about their rights and the implications of digital forensics on privacy and personal freedoms.

Whistle-blower Protections

Establish whistle-blower protections for individuals who report unethical or illegal practices in digital forensics agencies, ensuring their safety and anonymity.

Periodic Review and Revision

Regularly review and update digital forensics policies and practices to adapt to evolving technologies and legal standards, ensuring that human rights are adequately protected.

These policy recommendations aim to strike a balance between the need for effective digital forensics investigations and the protection of individuals' fundamental human rights. Policymakers should engage with stakeholders, including legal experts, civil society organizations, and technology experts, to develop and implement these policies effectively.

Policy Recommendations related to human rights in Multimedia Forensics

Human rights policy suggestions in multimedia forensics are critical to ensuring that investigative practices in this discipline respect individuals' rights and freedoms while addressing the issues posed by altered or misleading multimedia information.

The following are some major policy recommendations:

Regulatory Environment and Compliance

Create a legislative framework that clearly addresses human rights protection in multimedia forensics investigations.

Ensure that all multimedia forensics efforts, including digital media analysis and authentication, comply with current national and international laws and human rights standards.

Transparency and Accountability

Increase transparency in multimedia forensics operations by forcing investigators to thoroughly record their processes, tactics, and results.

Create procedures for monitoring and responsibility to ensure that investigators follow ethical and legal standards, with repercussions for violations.

Data Minimization and Informed Consent

In multimedia forensics, enforce data minimization rules, which state that investigators should only gather and analyse material that is directly relevant to an inquiry.

Before analysing multimedia content that contains an individual's likeness or personal information, seek informed consent from them wherever feasible.

Authenticity Verification Standards

Develop and implement standards for verifying the authenticity of multimedia material, taking into account the special requirements for photos, videos, audio recordings, and other media formats.

To safeguard the integrity of evidence, ensure that authentication methods are transparent and recorded.

Deepfake and Manipulated Media Detection

- Invest in research & development to create better tools and procedures for detecting deepfakes and altered multimedia material.
- Establish standards for the use of deepfake detecting technologies in order to avoid excessive monitoring or invasion of privacy.

Blockchain and Watermarking for Authentication

Encourage the adoption of blockchain technology or digital watermarking to generate immutable records of multimedia material, assuring its validity and source attribution.



Protection of Privacy and Consent for Public Sharing

Preservation of private and Consent for Public Sharing: Advocate for the preservation of individuals' private rights when multimedia content is publicly shared or utilised for investigative reasons.

Ensure that individuals' agreement is acquired when their media is utilised in investigations, especially in sensitive circumstances.

Media Retention Limits

Establish clear rules for the retention of multimedia evidence, taking into account the potential for misuse and the need to protect individuals' rights.

Training and Certification

Create required training and certification programmes for specialists in multimedia forensics, emphasising the relevance of human rights values and best practises.

Ensure that investigators have the knowledge and abilities required to handle multimedia evidence ethically.

Public Awareness and Education

Conduct public awareness campaigns and educational projects to educate individuals about their rights in relation to multimedia forensics investigations and the ramifications for their privacy and digital identities.

Ethical Guidelines

Create and promote ethical principles for multimedia forensics specialists, emphasizing the relevance of human rights, privacy, and ethical technology usage.

These policy suggestions seek to strike a compromise between the necessity for successful multimedia forensic investigations and the preservation of people' basic human rights. To properly design and execute these rules, policymakers should collaborate with stakeholders such as legal experts, civil society organizations, and technological experts.

Policy Recommendations related to human rights in Cyber Security

Human rights policy suggestions in cybersecurity are critical for striking a

balance between securing people' rights and protecting digital infrastructure and information. These suggestions are intended to guarantee that cybersecurity practices and policies adhere to human rights norms.

The following are some major policy recommendations:

Regulatory Environment and Compliance

Create and develop a legislative framework that expressly addresses human rights protection in cybersecurity initiatives.

Ensure that cybersecurity operations, including as monitoring, data gathering, and incident response, are in accordance with current national and international laws and human rights standards.

Privacy-by-Design

Encourage the incorporation of data privacy and security principles into the design and development of cybersecurity systems, tools, and practises.

Encourage organisations to perform privacy impact assessments to analyse the possible impact of cybersecurity measures on the privacy of persons.

Transparency and Accountability

Promote transparency in cybersecurity practices by requiring organizations and governments to disclose their cybersecurity policies and activities to the public, subject to national security considerations.

Establish mechanisms for oversight and accountability to ensure that cybersecurity efforts respect human rights and are subject to checks and balances.

Data Minimization and Retention Limits

Enforce data minimization principles in cybersecurity practices, where organizations collect and retain only the minimum necessary data for security purposes.

Establish clear rules for data retention limits to prevent unjustified data collection and prolonged storage.

Consent and Notification

Ensure that individuals are informed about and consent to data collection and monitoring activities whenever possible.



Notify individuals of data breaches and security incidents promptly, allowing them to take appropriate actions to protect themselves.

Protection of Encryption and Digital Security

Recognize the importance of strong encryption and digital security measures in protecting individuals' communications and data.

Avoid policies or regulations that weaken encryption or introduce backdoors, as they can undermine privacy and cybersecurity.

Access to Legal Remedies

Guarantee individuals' access to legal remedies and redress mechanisms when their human rights are violated in the context of cybersecurity activities.

Ensure that individuals have the right to challenge government or corporate actions that infringe upon their rights.

Ethical Use of Cyber Capabilities

Develop and enforce ethical guidelines for the use of cyber capabilities, particularly in military and intelligence contexts, to prevent human rights abuses. Suggest few guidelines

Promote responsible and proportional responses to cyber threats, avoiding disproportionate or indiscriminate actions.

Protection of Vulnerable Populations

Implement additional safeguards to protect the rights of vulnerable populations, including children, activists, journalists, and marginalized communities, who may be disproportionately affected by cybersecurity measures.

Public Awareness and Education

Conduct public awareness campaigns and educational activities to enlighten individuals about their rights in relation to cybersecurity practices and the possible impact on their digital life.

International Cooperation

Encourage international collaboration in cybersecurity initiatives while adhering to international human rights principles.

Promote the establishment of international agreements and standards that

emphasise human rights protection in cyberspace.

These policy proposals attempt to guarantee that cybersecurity measures and practises respect people's fundamental human rights. To properly design and execute these rules, policymakers should collaborate with stakeholders such as legal experts, civil society organisations, and technological experts.

Ethical and Legal Considerations in Digital Forensics, Multimedia Forensics and Cyber Security

Ethical and legal considerations play a crucial role in various aspects of the digital realm, including digital forensics, multimedia forensics, and cybersecurity. Here are some key ethical and legal considerations for each of these domains:

Digital Forensics

Consent and Privacy Rights

Ethical considerations: Digital forensic investigators must respect people's right to privacy. Before accessing digital devices or data, obtain sufficient approval or legal authority.

Legal: Violations of an individual's right to privacy without adequate authority might result in legal ramifications.

Data Handling and Chain of Custody

Ethical: To guarantee the integrity of evidence, maintain a rigorous chain of custody. To prevent tampering, properly document and safeguard digital data.

Legal: Courts need the chain of custody to be maintained in order for evidence to be admissible in legal proceedings.

Transparency and Honesty

Ethical: Transparency and Honesty Transparency must be maintained by recording all acts and choices made during an inquiry. Be open and honest about your findings and limits.

Legal: Giving inaccurate or misleading information might result in legal consequences and impair the investigation's credibility.

Impartiality and Biasness

Ethical: Maintain objectivity and avoid prejudice during the inquiry. Treat each party fairly and equitably.



Legal: Discriminatory practices or bias may result in legal challenges and evidence removal.

Multimedia Forensics

Digital Manipulation and Authenticity

Ethical: Verify the validity of multimedia information and correctly disclose any evidence of manipulation or fabrication.

Legal: Falsifying or tampering with multimedia evidence can result in legal ramifications and destroy faith in the court system.

Respect for Copyright and Intellectual Property

Ethical: Make certain that the usage of multimedia content is in accordance with copyright laws and intellectual property rights.

Legal: Illegal use of copyrighted content can lead to legal action and fines.

Cyber Security

Data Protection and Privacy

Ethical: Implement strong cybersecurity measures to protect sensitive data and persons' privacy.

Legal: ramifications of data breaches and privacy violations include legal liability, regulatory fines, and reputational harm.

Disclosure of Vulnerabilities

Ethical: Responsibly report detected vulnerabilities to appropriate stakeholders, such as software suppliers or organisations, in order to limit potential harm.

Legal: Failure to disclose vulnerabilities, particularly in vital infrastructure, may result in legal ramifications.

Cybersecurity Compliance

Ethical: Comply with cybersecurity regulations and best practices to safeguard data and systems.

Legal: Non-compliance with cybersecurity regulations can result in legal penalties and data breach notification requirements.

Ethical Hacking

Ethical: When doing security assessments or penetration testing, ethical hackers (white hat hackers) must act within legal limitations and with authorization.

Legal: Unauthorized hacking or vulnerability exploitation can result in criminal penalties.

In all three sectors, remaining knowledgeable about applicable laws and regulations, protecting individuals' rights and privacy, and upholding high ethical standards are critical for performing successful and legally sound investigations, digital analysis, and cybersecurity practices. Failure to do so may have major legal and ethical ramifications.

Capacity building and training

Capacity building and training are essential components of developing expertise and competency in the fields of digital forensics, multimedia forensics, and cybersecurity. To effectively build capacity and provide training in these areas, consider the following strategies:

Establish Clear Objectives

Define specific learning objectives and goals for the training program.

Identify the target audience, whether they are law enforcement professionals, cybersecurity specialists, or multimedia analysts.

Curriculum Development

Develop a structured curriculum that covers the fundamental principles, advanced techniques, and emerging trends in the respective field.

Ensure that the curriculum aligns with industry standards, best practices, and legal requirements.

Practical Hands-On Training

Incorporate practical exercises, case studies, and real-world scenarios to reinforce theoretical knowledge.

Provide access to tools and technologies commonly used in digital forensics, multimedia forensics, or cybersecurity.



Qualified Instructors

Employ experienced and certified instructors who are experts in the field.

Encourage continuous professional development for trainers to stay updated with the latest advancements.

Training Facilities

Set up dedicated training facilities equipped with the necessary hardware and software for hands-on practice.

Ensure a safe and controlled environment for cybersecurity training to avoid accidental security breaches.

Certification Programs

Offer certification programs from recognized organizations or certification bodies in the respective field (e.g., CISSP, CompTIA Security+).

Certifications provide tangible recognition of expertise and can enhance career opportunities.

Customized Training

Tailor training programs to the specific needs and skill levels of participants.

Offer both beginner and advanced courses to accommodate a wide range of learners.

E-Learning and Online Resources

Provide online training modules, webinars, and resources to accommodate remote learners.

Create a learning management system (LMS) for tracking progress and assessments.

Collaboration and Partnerships

Collaborate with industry organizations, universities, and government agencies to enhance training resources and access to expertise.

Seek partnerships with private sector companies for access to cutting-edge technologies.

Legal and Ethical Training

Include modules on legal and ethical considerations in each field, emphasizing the importance of adherence to laws and ethical guidelines.

Continuous Evaluation

Continuously assess the effectiveness of training programs through feedback, evaluations, and performance metrics.

Use feedback to improve and update training materials and methodologies.

Career Development Support

Provide guidance and resources for career advancement, including job placement assistance and networking opportunities.

Universities and Government Institutes plays a major role in career development support.

International Collaboration

Encourage collaboration and knowledge sharing with international counterparts to stay updated on global threats and best practices.

International reputed law enforcement agencies with the joint academic and hands on practices can help in enhancing the capability.

Research and Development

Support research initiatives and innovation within the organization or training institution to stay at the forefront of the field.

Capacity building and training in digital forensics, multimedia forensics, and cybersecurity should be an ongoing process to keep pace with the evolving nature of threats and technologies. By following these strategies, you can ensure that professionals in these fields are well-prepared and equipped to address the challenges and opportunities they encounter.

International Cooperation

Because of the worldwide nature of cyber threats and the need for shared expertise and resources, international collaboration is critical in the domains of digital forensics, multimedia forensics, and cybersecurity.

Here are some of the most important characteristics of international collaboration in these areas:



Information Sharing

Threat intelligence, including as indications of compromise (IOCs), attack trends, and vulnerabilities, should be shared among countries and Organisations. This enables a more complete picture of upcoming dangers.

Standards and Best Practices for Cybersecurity

Work together to create worldwide cybersecurity standards and best practices. These standards can contribute to the development of a uniform framework for safeguarding critical infrastructure and digital assets.

Legal Frameworks

Develop international legal frameworks and agreements to facilitate cooperation in cybercrime investigations and digital evidence sharing. Mutual legal assistance treaties (MLATs) and international agreements like the Budapest Convention on Cybercrime are examples of such efforts.

Capacity Building

Assist less developed countries in building their capacity in digital forensics, multimedia forensics, and cybersecurity. This can involve training programs, technology transfer, and knowledge sharing.

Joint Research and Development

Foster collaborative research and development projects to tackle advanced cyber threats. This can include joint projects on malware analysis, threat hunting, and encryption technologies.

Incident Response Coordination

Establish international incident response teams or networks to coordinate responses to large-scale cyber incidents that may transcend national boundaries.

Cyber Exercises and Drills

Participate in international cybersecurity exercises and drills to enhance preparedness and improve incident response capabilities.

Public-Private Partnerships

Encourage cooperation between governments and the private sector. Private

companies often possess critical cybersecurity expertise and infrastructure that can be leveraged to combat cyber threats.

Cross-Border Collaboration

Facilitate cross-border collaboration among law enforcement agencies, cybersecurity firms, and academia. Cybercriminals often operate across national borders, making international cooperation essential for investigations and prosecutions.

Diplomacy and Conflict Resolution

Use diplomatic channels to address cyber conflicts and establish norms for responsible state behavior in cyberspace. The United Nations Group of Governmental Experts (UNGGE) has been involved in such discussions.

Cybersecurity Awareness Campaigns

Collaborate on international cybersecurity awareness campaigns to educate the public and organizations about cyber threats and best practices.

Multilateral Organizations

Engage with international organizations such as INTERPOL, the United Nations, and regional bodies like the European Union to promote cybersecurity cooperation.

Norms and Rules of Engagement

Work towards consensus on norms and rules of engagement in cyberspace to prevent cyber conflicts and escalation.

Mutual aid in Cybercrime Investigations

Create procedures for mutual aid in cybercrime investigations, such as extradition treaties and digital evidence exchange.

International collaboration in digital forensics, multimedia forensics, and cybersecurity is critical for dealing with the growing and more complex cyber threats that affect governments, organisations, and individuals all over the world. To establish a safer and more secure digital environment, governments, industry stakeholders, academics, and international organisations must work together.



Conclusion

To summarize, incorporating human rights issues into the domains of digital forensics, multimedia forensics, and cybersecurity is not only a moral obligation, but also a core pillar of responsible practice in these crucial disciplines. Individual rights, privacy, and freedom of speech are becoming increasingly important as technology advances. Finding a harmonic balance between security and human rights is a complicated and dynamic task that necessitates continual collaboration, commitment to ethical values, and observance of legal frameworks.

By upholding human rights and incorporating them into every aspect of our approach, we can ensure that our efforts to secure cyberspace and investigate digital incidents are not only effective, but also just, ethical, and respectful of the fundamental rights and freedoms of all individuals in our interconnected world.

Chapter 11

Forensic Psychological Investigation Techniques for Safeguarding & Felicitating the Human Rights

Dr Priyanka Kacker ¹

1. Introduction

“We must take sides. Neutrality helps the oppressor, never the victim. Silence encourages the tormentor, never the tormented. Sometimes we must interfere. When human lives are endangered, when human dignity is in jeopardy, national borders and sensitivities become irrelevant.” - Elie Wiesel

During a Criminal Investigation, the protection of Human Rights is followed through the “Right to Remain Silent - Section 161 of the Code of Criminal Procedure, 1973 grants the right to remain silent during interrogation by police. Section 313(3) of the CrPC, 1973 protects the accused and allows him to remain silent at the trial”, “Right against Self-Incrimination - the Indian Constitution under Article 20(3) provides immunity to an accused against self-incrimination – “No person accused of an offence shall be compelled to be a witness against himself”, & “Right to Privacy - a fundamental right under Article 21 of the Indian Constitution that individuals have a right to privacy in matters such as their personal information, communication, & other private matters”. These rights are followed to protect the individual assuming the suspect is innocent and that every suspect has the right to remain silent, has the right to restrict one’s statement which can lead to self-incrimination and has all rights to maintain their privacy. During the investigation the rights of the suspect are given due consideration however, the equal rights of the Victims and their family members get violated. The victim has not only witnessed and lived through the criminal act but also undergone the trauma of repeating the statements, revealing private information and most of the time being blamed for the crime that happened.

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Of course, human rights need to be protected but re-evaluation of protection of such rights are required for the investigation of heinous crimes, atleast for cases on trial for more than 5 years, Crimes against Women, Children & Elderly; the rights should be relaxed and need full investigation without any barriers.

In a written statement submitted by the Law Minister Mr. Arjun Ram Meghwal in Rajya Sabha; across India, over 5.02 crore cases are pending in various courts. As per Mr. Meghwal the causes of the case backlog were non-availability of adequate numbers of judges and staff, complexity of cases and a lack of processes. However, the pendency is not limited to the reasons given by Mr. Meghwal. Furthermore, reasons are lack of awareness about the existing Forensic Psychological Investigation techniques, misrepresentation and misinterpretation of the “Right to Remain Silent”, “Right against Self-Incrimination”, and “Right to Privacy”, false allegations, lack of awareness about the process, poor counselling services, misguidance by advocates and the stringent guidelines for Forensic investigations.

Forensic psychological investigation technologies are being criticized without understanding their mechanism and standard operating procedure. It is believed that the Forensic Psychological Investigation Techniques are harmful, against human rights and torturous. However, Forensic Psychology and its Psychological Investigation techniques protect the rights of human being by removing the fear of third-degree, fear of torture, fear of injustice, fear of death, fear of not being heard, and promotes the process of justice in a humanitarian way. It also protects the “Right to remain silent”, “Protection from statements of Self-incrimination” and “Right to Privacy” as the Consent of the subject is taken before administrating the techniques for the investigation. Forensic psychological techniques like Polygraph, Layered Voice Analysis, Brain Electrical Oscillations Signature (BEOS) Profiling, Eye-Detect, Micro-expressions systems, Visual Stress Analyzer and suspect Detection Systems are non-invasive, scientific, and with high accuracy based upon the answers given by the person under investigation as per their will with their consent. The questions asked during the investigation are non-judgmental, simple questions without a compulsion to tell the truth. Especially the BEOS technique; where no questions are asked and no verbal responses are expected from the subject during its administration. The person has all rights reserved to not respond mentally by not remembering the event in which the person has participated. Also, these systems present the questions and probes based on the statement given by the subject under investigation. These techniques help in detecting

the deception and level of involvement of an individual in the criminal act and can also discriminate between the Victim, the perpetrator and the eye-witness if used quietly and comfortably by a well-trained forensic professional i.e., a Forensic Psychology Expert.

Like any medical diagnostic instrument at the hospital for example MRI, CT scan, EEG, PET Scan, X-ray etc. which helps in the diagnosis of the disease for deciding the best treatment option for the patient; forensic psychological investigation techniques also support the individual who undergo the investigation to prove their innocence. If the individual is found to be deceptive and involved in a criminal act that leads to justice for the victim. The lack of awareness and the misrepresentation of the techniques are the main grounds for pending cases and injustice to many.

It is said that “Justice Delayed is Justice Denied”. The delay in justice happens because of the lack of forensic training of the Police Officers who deal with: Crime Scene Management, the traditional process of interrogation, pressure to solve the case with limited evidence or no evidence and the lack of understanding about the technologies available for investigation. The same applies to defense lawyers and judges.

Forensic Psychology can safeguard the Human Rights Act mandates of the NHRC. Forensic Psychological Investigation technologies can proactively inquire into violations of human or negligence of such violation by a public servant. Forensic psychological investigation technologies can help in understanding the level of involvement of an individual in a criminal act. Cases like sexual assault, child abuse, elderly abuse, Domestic Violence, Rape, Sexual harassment at the workplace, terrorism, white collar crimes, and criminal acts by Juvenile delinquents can be investigated through these non-invasive psychological technologies like Polygraph, Layered Voice Analysis, Visual Stress Analyses, Micro-expressions system, Brain Electrical Oscillations Signature (BEOS) Profiling & Eye-Detect. For the investigation and the journey to find the truth, the techniques apart from suspects/offender/perpetrators can also be administered to Victims, Children and the elderly to investigate the abuse and criminal acts they have undergone.

These techniques can add immense value to the existing legal framework of the country by reducing the burden of proof on victims of domestic violence who have to, most often, endure these crimes behind closed doors. The current legal channel is more offender-based. These techniques advocate for a victim-



centered framework for cases, especially of violence and abuse. This can make victims a crucial part of the process and allow them to make their voices heard and share their trauma. This would also minimize the repeated trauma of the victims and not trap them in cycles of victimization. Further, adds immense scope for forensic psychologists to facilitate ethical and sensitive treatment of victims of heinous crimes as they navigate the legal channel. A forensic psychologist could provide counselling intervention, as well as facilitate legal or other forms of aid that the victim might need, populating greater resources that a victim might need.

2. Current Landscape of Forensic Psychology Investigation

Currently, the initial collection of evidence, interrogation and further crime investigation is done by the Police as investigation officers lead to the presentation of charge sheets against the suspect in the court. Once the case is presented on board the trial begins. Concerning the physical and other evidence presented and defended at court; if the defense lawyer requests the court for forensic psychological investigation only then with the consent of the suspect the court orders for the forensic psychological investigation of the suspect and send the case to the forensic laboratory. Ideally, forensic psychological investigation shall be mandatory for all types of criminal cases.

Forensic Psychological Investigation Techniques: The court can order any one of the forensic psychological investigation techniques or a combination of multiple techniques depending upon the request made by the defense lawyer. The techniques usually being ordered by the court are polygraph, narcoanalysis, Brain Electrical Oscillations Signature (BEOS) profiling, and layered voice analysis for investigation.

The Standard Procedure of Forensic Psychological Investigation Techniques followed are: As per the courts' order the forensic psychology expert follows the following Standard Operating Procedure for the investigation of a case. Suspects and eyewitnesses undergo such techniques depending upon the permission of various techniques given by the court.

Step I: Administration of Psychological assessment: Suitable psychological tests based on the psychological questionnaire, Behavioural Analysis Interview, Attitude towards crime, and verbal and Non-verbal observation were administered to the suspects. The above-mentioned assessments are administered in a private, commodious and soundproofed room to establish rapport with the suspected

person. It is done in extreme detail and follows a well-structured format. If required, a mental Status Examination of the subject is done based on his mental status during the initial interview. Mental status Examination includes the subject's appearance, speech, motor activity, mood, Affect, thought process, thought content, insight, perceptual disturbance and judgment. Such psychological tests aid the making a psychological profile of the suspect and indicate the focus areas before subjecting the suspect to any other psychological investigation.

Step II: Forensic Interview: The forensic psychology expert conducts the forensic interview to gather all the necessary panorama information about the case. Visiting the crime scene is also a requirement for the expert to have all verified information about the case, suspect, his version etc. before the forensic psychology expert conducts the Forensic Psychological Assessment. The Procedure includes different stages by defining the problem, available circumstantial information of the suspect and observation by directly assessing the subject with the help of interview techniques. Some important documents e.g., FIR copy, brief construct of the case, statement of the subject, Crime scene report, in case of violent crime medico-legal certificate, in case of murder; post-mortem report and issues to be probed are required before assessment of the subject. The forensic psychology expert also includes information from other sources of crime and its police record, any possible history of psychiatric illness, or previous crime record, if any. Analysis of the gathered data through forensic interviews, verbal and non-verbal observations and interpretation of psychological test reports are then interpreted concerning the norms of the subject.

Step III: Consent: A forensic psychological investigation is not possible without the suspects' consent. After the administration of the psychological assessment, facts and evidence collection from the Investigation Officer and the forensic interview of the suspect the forensic psychology expert takes consent of the suspect. An explanation about the forensic psychological investigation technique is given to the suspect so that the suspect undergoing the recording has full information about the technique and if there is any myth or misunderstanding about the technique then those queries are resolved by the expert. Queries by the subject are also answered to make the subject feel relaxed before undergoing the recording. The subject has the full right to deny giving consent before or during the recording. After the subject gives consent, further psychological investigation is done.



Step IV: Forensic Psychological Investigation Techniques: As per the court's order to conduct various psychological investigations the forensic expert explains about the technique to the subject, takes the subject's consent and then conducts the recording. If two or more than two investigation techniques are ordered by the court for example Polygraph, Narcoanalysis and then BEOS testing is done in series.

Step V: Report: Based on the result gathered through psychological assessment, MSE and especially the forensic psychological investigation technique the report is written with an unbiased approach to render court about the involvement of the subject in the criminal activity. The report is submitted directly to the court.

However, the standard operating procedure needs to be modified as per the requirements and urgency of pending cases and newly reported cases. Following are the requirements that need to be implemented for Forensic Psychological Investigations for better investigation and to deal with the pending cases:

1. Forensic Psychology Aid: Justice is a right of every human being. A crime that happened creates three major categories of people for investigation i.e., Victim/s, suspect/s and eye-witness/s. These three categories of people shall get justice and Forensic Psychological Investigation techniques can be an aid to provide justice. The case investigation starts at the Crime Scene. For proper investigation, the forensic psychologist starts their investigation from the Crime Scene which can be captured through a 360-degree camera-based recording for the Crime Scene Management, Forensic Interview of the victim (if alive), relatives, family members, eye-witness/s and the suspect/s. Once a case is registered the case shall be referred to a forensic psychologist associated with the Police department either as a full-time employee or as a consultant. The case shall be studied by the forensic psychology expert to:

Categorization of the case registered: The case registered needs to be studied by the Forensic psychologist to categorize the case into different categories like Civil, Criminal, Sexual Assault/Rape/Harassment, Marital Issue, Domestic Violence, POCSO, White collar Crime etc. This will help in doing the initial forensic interview and if required the counseling of the victim and relatives. Most of the time the cases are registered in haste with a lack of proper background and understanding about the consequences of filing the case and its effect on families, especially children. The proper involvement of a forensic psychologist will help the complainant to understand the legal as well as the psychological

consequences of the case filed. It will also help the Police department to avoid baseless cases that are being registered in haste and lack legal evidence.

i.) Forensic Counselling: As per the complaint filed by the complainant proper counselling will help the complainant to maintain the psychological balance to help the victim and their family members take proper decisions, especially in cases like Criminal, Sexual Assault/Rape/Harassment, Marital Issues, Domestic Violence, POCSO. Proper and timely forensic counselling will help the complainant and the person against whom the complaint has been filed to do the court settlement and resolve the family conflicts in a much humanitarian way which is usually not possible after filing an FIR, divorce case, child custody, or POCSO cases.

ii.) Forensic Interview: In severe/complex/heinous crime-based cases the forensic interview of the victim, suspect, complainant, relatives, family members, and eye-witnesses from the first day of registration of the complaint will be helpful in multiple ways. The forensic interview shall be done by a Forensic psychologist irrespective of the type of crime and gender age of the subjects. In case of the non-availability of a Forensic Psychologist at the Police station; the forensic interview can also be done through digital media through online conferencing where the interview shall be done by the Forensic psychologist with the victim/suspect/eye-witness at a mutually convenient time which will make the victim/suspect/eye-witness feel comfortable to give their statements in a much-relaxed environment which is usually not possible at offline mode sitting at the police station where the victim/suspect/eye-witness feel under pressure and traumatized. Since the entire forensic interview will be audio-video recorded the recording can be further used for chargesheet, filing the case, case revision and for forensic psychological investigations like polygraph and layered Voice Analysis (LVA): for preparing questions; BEOS profiling: for preparing probes; Micro-expressions detection of deception. This will reduce the time taken for investigation, reduce the time taken for repeated interviews and statements of the victims/suspects/eye-witness and over and above it will help in reducing the trauma the victim/suspect/eye-witness undergoes during the entire investigation and trials. It will give an overall package of information for investigations in one go using a digital platform.

Following are the human rights protecting guidelines followed during forensic interview:



a)	Components of Interview	<ol style="list-style-type: none">1. Orientation2. Narration and Questioning3. Summarizing4. Closure
b)	Guidelines	<ol style="list-style-type: none">1. Set the location of interview.2. Set the goal of interview.3. Review relevant documents in advance and have them ready.4. Be aware of any cultural, gender or racial issues that may be present.
c)	Location	<p>Preferable neutral location for complainants and complainer. Ensure the location is:</p> <ol style="list-style-type: none">1. Private2. Comfortable3. Clean4. Properly equipped Audio Video recorder Setup5. No distractions or interruptions such as telephones
d)	Interview goal	<ol style="list-style-type: none">1. Ensure the Suspect's understands the process2. Gain the suspect's willingness to cooperate now and in the future3. Establish a rapport with the Suspect4. Assess their non-verbal communication5. Obtain a complete and truthful statement
e)	Interviewing process	<ol style="list-style-type: none">1. Ensure the comfort of the suspect – Water, washroom2. Advice the suspect there may be difficult questions3. Using audio video recorder. Why?4. Reassure the suspect that he/she have to tell everything which is asked5. Allow the suspect to take break if needed
f)	Interviewing Techniques and Skills	<ol style="list-style-type: none">1. Orientation2. Before the interview begins3. Explain why they are there and how they can help4. Ask the interviewee if he or she has any questions

g)	Establish rapport	<ol style="list-style-type: none"> 1. Likeability factor – People will give more information and cooperate more with someone they like 2. Helps to determine the baseline – Reactions and general behavior may be compared to more stressful periods during the interview.
h)	Narration & Questioning	<ol style="list-style-type: none"> 1. By following format, initially avoid questions that have a yes or no answer 2. Make sure that your questions are clear enough 3. Avoid embarrassing & demeaning terms which are not related to crime 4. You can also ask question by showing picture or a document
i)	Question Approach	<ol style="list-style-type: none"> 1. Avoid leading questions that suggest an answer 2. Once the interviewee has shared the demographic detail, ask direct questions related to case and trapping day to fill in gaps and clarify 3. You can use reference points as necessary, but do not suggest an answer
j)	Probing	<p>Not all suspects will be forthcoming with information</p> <ol style="list-style-type: none"> 1. Answering questions with questions 2. Repeat the question as you originally asked it 3. Phrases like “that’s basically it” or “I guess that’s all I can remember” <p>Consider this an admission that he/she has more to tell – keep probing</p>
k)	Consent	<ol style="list-style-type: none"> 1. Assume what you write or say will be listen and seen by all 2. Ask the interviewee to sign them 3. Consider Legibility

iii.) Forensic Psychological Assessments: Forensic Psychological assessment is an integral part of forensic investigation to diagnose the mental stability of the suspect and readiness to face trials in court, especially for insanity defence, insanity plea, malingering and related cases. Looking at the pandemic situation the subjects can be brought to the forensic laboratory for forensic psychological assessments. The paper-pencil-based forensic psychological assessments can be converted into digital format through an APP or converting the paper-pencil-based questions into an Excel sheet using Google Forms for data collection, analysis and reporting. However, care must be taken that the Google forms



shall be filled by the suspect during the online interview in front of the forensic psychologist so that if there is any difficulty faced by the respondent (suspect) to answer any question in the forensic psychological assessment that can be taken care by the forensic psychologist and also to make sure that the answers are given by the person under scrutiny and by some other person.

If any mental instability is found through the forensic psychological assessment of the suspect, then the suspect can be referred to a Forensic clinical Psychologist for therapy and interventions which can be done through digital mode.

Forensic Psychological Investigation: As the filing of complaints, forensic interview and forensic assessment is done through digital mode it will be easier for the forensic psychological investigation team to prepare content for the forensic psychological investigation techniques like polygraph, BEOS profiling, Micro expressions detection of deception and LVA for Voice spectrography. The LVA and micro-expressions analysis can be done without the physical presence of the suspect. For forensic psychological investigations like polygraph, and BEOS profiling once the questions and probes are ready using digital material collected through the complaint, forensic interview and forensic psychological assessment the suspect can be brought to the forensic laboratory for final recording on the systems like polygraph, LVA and BEOS profiling after following the traditional method of court's permission and consent of the suspect.

Forensic Rehabilitation: Forensic Rehabilitation is the most neglected field in the Indian set-up yet most vital in community set-up. Suspects who are behind bars due to ongoing trials, prisoners, juveniles and the victims and their family members require proper counselling and rehabilitation. Due to a lack of proper resources and several forensic psychologists in India such facilities are not available at every prison and to every individual undergoing forensic investigation, trials and imprisonment. The pandemic has allowed forensic rehabilitation through the digital portal where forensic psychologists with the help of the Prison superintendent and other officials can start online rehabilitation modules for the rehabilitation of prisoners, victims and juveniles. This will help to reach out to the major population in less time and help the community to rehabilitate the prisoners, victims and especially juveniles. Online counselling, activity-based modules and special sessions on awareness of the consequences of criminal acts, human rights, legal implications, and vocational training can make a lot of difference with less funding for such initiatives.

Psychological Autopsy: Many suicide cases underwent psychological autopsy. However, the SOP for this is still not clear and ultimately leads to the trauma of family members, and unsolved cases and violates the rights of the person under scrutiny, the family members and the deceased too.

3. Key Technological Advancements

Forensic Psychological Investigation techniques are scientific and advanced with upgraded Manuals and SoPs for hands-on training which are used for safeguarding Human rights and not for violating human rights. All these techniques are non-invasive, user-friendly, easy to administer and subject-friendly which can be administered on both adults and children. In the case of minors, it can be administered with the consent of the parent/guardian.

Each technology is dependent on the Forensic interview. The forensic interview is conducted at forensic labs and is different from the interrogation done at the Police station. For the preparation of these forensic psychology techniques-based investigation the forensic interview is done under a closed, private set-up by a trained forensic psychology expert. The questions asked are limited to the case under investigation and as per the information shared by the Investigation officer which is based on the evidence collected. No pressure is created to give a statement against the will, no compulsion is made to tell the truth and no private information is asked which have no relevance to the case under investigation thus, the forensic psychological techniques protect the “Right to Remain Silent”, “Right against Self-Incrimination & the “Right to Privacy. The raw data & results can be checked by the court at any point of investigation for clarity.

Following are advanced techniques available for Forensic Psychological Investigation:

a) Audio Video Aided Forensic Interview Set up - An SOP based set-up is used for audio-video recording of suspect’s statements for systematic recording and conducting forensic interviews under the supervision and guidance of a Forensic Psychology expert. Such recording helps keep a pressure-free, stress-free environment for the individual under investigation to state as per their will. Since it is an audio-video recording Forensic Interview is a more systematic, goal-oriented, case-specific, closed & private set-up to make the individual comfortable, free from apprehensions and fearless while giving a statement. The set-up consists of a microphone for audio recording and two cameras focused



on the Interviewer and the interviewee to monitor verbal and non-verbal cues to create a fearless environment. Uncut/unedited version of the recording in CD submitted to the court in a sealed envelope. The same is submitted to the Investigation Officer and to the defense lawyer (if requested) for preparation of the case. The benefit of such audio-video recording is that a statement is taken once in a comfortable, fear-free environment by a neutral person (forensic expert) and the statement can be re-heard and re-evaluated again and again without torturing the individual under scrutiny. The recorded interview can be further used for Layered Voice analysis, preparation of questions for polygraph testing and probes for BEOS testing, The video can be used for Visual stress analysis and micro-expressions.

Polygraph (Lie Detector System) - It is the detection of deception through changes in the physiological parameters of suspects. When the suspect attempts to speak lies, it measures changes in the physiological parameters such as blood pressure, skin resistance, respiration, heart rate and body movement.

Suspect Detection System - This technology is capable of screening and detecting the hidden “hostile or unfriendly intent” before they commit their intended acts. Even after a crime has been committed, the system can quickly identify criminals from a general population set of suspects.

Brain Electrical Oscillation Signature (BEOS) Profiling - It measures the remembrance and participation in a criminal act of a person under investigation. The memory of the entire crime gets saved as signatures in the perpetrator’s brain. This system is used to investigate the level of involvement of the subject under investigation as an actual perpetrator or an individual having a brief knowledge of committing the crime as an eyewitness. The probes are prepared based on the statement given by the suspect and by the Investigation officer considering the evidence presented. The subject while undergoing BEOS administration is not asked any questions and no verbal response is expected.

Layered Voice Analysis - It detects the speaker’s underlying emotion regardless of the language or tone of the speech. This technology operates to track the genuine emotion reflex, which reveals the speaker’s true sensations and feelings to detect deception.

Eye Detect System - The tendency of any individual who is lying can be detected by the movement of the eyes. The higher the cognitive load, the greater the consequences of the lie. Eye Detect monitors pupil diameter, eye

movement, reading behavior, blinks, fixations, and other factors contributing to the detection of deception. Further, it can be administered with a polygraph. The greater the consequences of the lie, the greater the emotional reaction and increase in cognitive load. This affects both the brain and the body's physiology. Eye Detect with polygraph measures changes in the eye's blink rate and movement, heart rate, respiration and skin conductance. Participants answer True/False questions on a computer. The infrared camera records eye behavior. The Physio Tracker records cardiovascular activity, skin conductance, and respiration activity. When the test concludes, all of that data is uploaded to a secure web server for analysis. A person's credibility score is immediately calculated. The results are simple: truthful or deceptive.

Visual Stress Analyzer: Visual Stress Analysis focuses on detecting, measuring, and analyzing stress visually. It uses biosensors to assess the skin's temperature, the electrical activity of the heart, GSR, breathing patterns, blood pressure, and heart rate to analyze stress. Artificial Intelligence is used to track the subject using the PPG (Photoplethysmographic) Algorithm and Statistical HRV (Heart Rate Variability Parameters).

Micro-expressions system: It is one of the most comprehensive, psychometrically rigorous, and widely used systems for manual coding of the facial muscles, called action units. The system analyses the video-recorded facial behavior in frames in slow motion, coders can manually code nearly all possible facial expressions into action units. It gives accurate coding of different facial muscle movements observed in the video frames of the subjects to draw a meaningful conclusion about their latent emotions and feelings along with its veracity, concerning the context they are asked using an interview schedule.

4. Policy Recommendations

To fulfil the need to protect human rights with the proper application of Forensic Psychological Investigation Techniques requires the following implementations under a separate policy:

4.1 Data Management and Sharing

For the establishment and maintenance of Forensic Psychological Investigation databases, emphasizing data security, privacy, and international cooperation for cross-border data sharing. Data management is critical to ensure the acquired data is stored and protected in a standardized manner. The following practices would ensure the same:



- a) Encrypted files for each investigation case.
- b) Password-protected files for each investigation case.
- c) Password-protected files can be saved on the password-protected hard disk.
- d) Creation of a password-protected cloud database which can be accessed by limited authorities.
- e) An independent team who can submit a confidential report directly to the court.
- f) Interference of any other agency shall not be permitted/entertained.
- g) Sharing of crime-related details on social media by the public without formal permission shall be considered a serious offence.
- h) Only the concerned people directly related to the case shall get timely updates about the case. It shall not be made public (To avoid mental trauma faced by the family members, relatives, especially the victim)
- i) The general public shall be motivated to get updates about the case they are interested in; from the articles/papers published by the Forensic experts in reputed journals and the final judgment given by the court.

4.2 Quality Control and Standardization

- a) To formulate a special team of Trained Forensic experts for forensic psychological investigation.
- b) The forensic investigation teamwork shall start from the crime scene to the final phase of the case i.e., the judgement.
- c) SOP to be followed by all the Forensic Laboratories and professionals involved in Forensic Psychological Investigations. The SoPs must include the guidelines for conducting the interview of Victims, suspects, family members, relatives, and eyewitnesses during the Crime Scene Investigation, Case history, forensic interview at the forensic lab, forensic psychological technique procedure with steps of analysis, report format etc.

4.3 Research and Development Funding

Policy to give emphasis & increased funding for research and development in Forensic Psychological Investigation, enabling the adoption of cutting-edge technologies and methodologies. Government and private agencies shall include funding opportunities for forensic psychology-based research including development of technology, application of technology in various criminal cases,

patents, and publications.

4.4 Interdisciplinary Collaboration

Collaboration between forensic scientists, legal experts, and policymakers to develop comprehensive strategies and for the exchange of knowledge. Strengthening collaboration between forensic science institutes, universities, and law enforcement agencies can facilitate the dissemination of resources, expertise, and standard protocols and practices. Encouraging interdisciplinary research, conferences, workshops, seminars and training programs across the country will provide a common platform for forensic scientists, legal professionals, and policymakers, thus, cultivating a better understanding of the potential of forensic science in the Indian context.

5. Ethical and Legal Considerations

5.1 Privacy Protections

Robust privacy safeguards in psychological investigation-based databases, including informed consent, limitations on data retention, and protection against unauthorized access. The following measures can be taken to protect the privacy of data involved in a forensic psychological investigation:

- a) Restrict the disclosure of confidential and sensitive data related to the case.
- b) Convert the data in the form of encrypted files.
- c) Frame policies and protocols specifically to be used during forensic investigation to preserve and protect the data collected.
- d) Promoting training and workshops regarding the use of the latest technologies and techniques to handle data and maintain its privacy and confidentiality specifically for investigators, law enforcement officials, and other forensic experts.
- e) Implement a forensic investigation framework that respects and maintains data privacy and confidentiality
- f) Avoid media coverage & media publicity till the case is reported to the court and the final Judgement is given.

5.2 Benefits of the Psychological Investigation Techniques

Provide guidelines on the use of Psychological Investigation Techniques, its benefits and application in various types of cases to balance its potential benefits with ethical concerns and potential misuse.



5.3 Regulation of Emerging Technologies

A regulatory framework for emerging Forensic Psychological Investigation technologies, ensuring responsible use and preventing unintended consequences.

- a) For the use of any new technology, institution-based research work on the Indian population shall be made mandatory before implementing it for investigation.
- b) The research must include the Indian population for testing of technology and its results.
- c) For such research work, provision for research and development funding shall be provided by the company promoting the product and/or technology partially funded by the Government of India.

6. Capacity Building and Training

6.1 Infrastructural Development

Investment in state-of-the-art laboratory infrastructure, including equipment, facilities, and IT systems. Upgrading infrastructure will enable laboratories to handle the following advanced, highly accurate, scientific & non-invasive Forensic Psychological investigation techniques efficiently: Polygraph, Layered Voice Analysis (LVA), Suspect Detection System (SDS), Eye Detect, Brain Electrical oscillation Signature (BEOS) Profiling, & Visual Stress Analyzer (VSA) with common SOPs and trained Forensic Psychology Experts.

6.2 Workforce Development

- i. **Recruitment:** Recruitment of Forensic Psychologists at Police stations, courts, Forensic laboratories, rehabilitation centres, prisons, hospitals and Legal Aid centres with a minimum eligibility criterion of a Master's degree in Forensic Psychology from a reputed University. The selection process shall be a skill-based evaluation where the candidate should be asked to demonstrate the administration of the technique, analysis of the results generated and reporting skills.
- ii. **Consultation:** The officers can discuss their cases and get a direction to choose the type of investigation they can go ahead for forensic psychological investigation on a case-to-case basis and forensic interview.
- iii. **Forensic Assessment:** To understand the victim/suspect/eye-witness's mental status and its competency to stand trial or insanity plea. NFSU can give assessment reports for understanding the psychological health of people under investigation.

- iv. Training, Certification & Licensing:** A well-scrutinized training, certification and licensing programs need to be initiated from which the Psychology professionals can get training, get skilled in the administration of the techniques and can practice with the license to avoid any malpractices. Training of Police officers, advocates, judges, forensic sciences experts and professionals who are directly or indirectly involved in investigation shall get training about the techniques, its application, and its interpretation.

6.3 Public Awareness Programs

public education campaigns to raise awareness about the benefits, limitations, and implications of Modern Forensic Psychological Investigation technologies for crime investigations, fostering a better-informed society. Educating the public is one of the most important strategies to prevent crime. Public awareness programs designed around the Prevention of Crime will indicate the existence of a problem, the way to handle it and action to be taken. This will contribute to reducing the risk of criminal activities and building a safer community.

The following activities can be a part of the Public Awareness Programs:

- a) Design and distribute an informative resource pamphlet/booklet targeting general issues and the action to be taken.
- b) Role-plays and skits performed by youth in public places about crime and its prevention.
- c) Brochures, posters, programs on television, radio, social media, and posts/blogs in order to hold and capture public attention
- d) Launch a bulletin or magazine based on the theme of Forensic Psychology.
- e) Conduct some quiz or contest to spread awareness among the public.

7. International Cooperation

7.1 Global Standards

Establishment of international SoPs for Forensic Psychological Investigations, Interviews, analysis, data sharing, and collaboration to facilitate seamless cooperation across borders.

7.2 Joint Investigative Efforts

Collaborative efforts between countries in cases involving cross-border crimes, emphasizing the role of advanced Forensic Psychological Investigation techniques in transnational investigations.

8. Conclusive remarks

A separate policy is recommended for the implementation of Forensic Psychological Investigation techniques as it safeguards & felicitates human rights. A separate policy is obligatory for providing Counselling to the Victims, family & relatives; for sacking third degree; to creating awareness, sensitivity & training programs for stakeholders about the scientific aspects of the techniques for their wide applicability; dismissal of pending cases; prevention of cases based on false allegation. The research, infrastructural development & global collaborations shall also be part of the policy implementation. Since the National Forensic Sciences University (NFSU) is known for its state-of-the-art infrastructure and for providing all the facilities; the benefits of these services can be taken for policy preparation & execution. Further, a reconsideration & re-evaluation of the implementation of human rights needs scrutiny for relaxation during the forensic psychology investigations, especially in cases of heinous crimes, and crimes against women, children & elderly as it's a fact-finding technique to felicitate justice. A crime has already violated someone's human rights so a forensic psychological investigation to find truth cannot be put under the scrutiny of violation of rights. It shall be perceived as protection of the rights of the victim, innocents, family members and the deceased.

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Chapter 12

Forensic Ballistics in Criminal Justice System

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1. Introduction

Ballistics has been defined as the study of projectile and its dynamic behaviour within the gun barrel, a medium like air, and eventually into or through a target. The science of ballistics is typically classified into three major categories:

- I. Interior ballistics: The study specific to the firearms and projectile movement along with the thermodynamic behaviour within the barrel is broadly covered under the study of interior ballistics.
- II. Exterior ballistics: The kinematics involved in the projectile movement and the study of trajectory path when it travel in the specific medium, predominately in the air are studied in exterior ballistics.
- III. Terminal ballistics studies the projectile behaviour, impact mechanics and damage assessment once it interact with the target . In case if the person is target, the study is termed as a wound ballistics [1].

In forensic ballistics, bullets and their impacts are analysed to produce data that can be used by a court or other legal entity. Separate from ballistics data, examination of firearm, ammunition, spent cartridge case & tool mark analysis (sometimes referred to as “ballistic fingerprinting”) are being carried out to determine whether a certain weapon or tool was used in the commission of a crime [2].

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2. Current Landscape of Forensic Ballistics

The amount of violence brought on by firearms has significantly increased over a period of time. The events like homicides, suicides, murders, robberies, assaults, terrorism, and many more crimes involved the usage of firearm. To overcome difficulties like these, forensic science has been helping criminal investigative agencies either obtain evidence against a criminal or assist in removing spurious evidence against a suspect who may be an innocent.

A subfield of forensic science known as forensic ballistics deals with the techniques used to identify weapons and ammunition in order to address issues related to shooting occurrences during criminal investigations. In order to help criminal investigation agencies link a suspected firearm to a crime scene or rule it out of the equation, firearm examination comprises analysing weapons, cartridge cases, and spent bullets. In criminal investigations involving weapons, evidence may only contain traces of discharged bullets or casings. In such circumstances, it is necessary to track down any firearms that may have been used in the crime.

One of the most important steps in the investigation process is being able to pinpoint the specific firearm from which the bullet was discharged. Depending on the different features of its numerous parts, including the firing pin, barrel rifling, ejector, extractor, and breech face, each firearm demonstrates distinct characteristics. These markings, including a “casing signature” and a “bullet signature,” which are considered to be particular and unique to each firearm. These features make it feasible to identify the weapon used in the crime on the basis of its characteristics. These traits may be brand-specific, allowing one to identify a certain type of firearm, or they may be specific to each firearm, allowing one to distinguishably identify each firearm. The former type of features are referred to as “Class characteristics,” whilst the latter are known as “Individual characteristics” [3].

At this time, the majority of forensic science laboratories recognize firearms identification as an essential component. The analysis of a range of relevant evidence may fall under the purview of many laboratories’ firearm section. These examinations include:

- A. Examine submitted firearms to determine the maker, model, caliber, serial number, and functionality.



- B. Examining the evidence of bullets and cartridge casings in conjunction with the firearm submitted as evidence to determine whether any or both were shot into or from the weapon.
- C. Evaluation of ammunition used as evidence to identify the manufacturer, bullet type, and country of origin.
- D. Analysis of gunpowder patterns on a variety of submitted evidence, including submitted firearms and ammunition components, clothing, glass, flesh or hair.
- E. Reconstruction of a shooting scene using trajectory analysis to ascertain the order of two or more events in a specific incident using data generated from the physical evidence.
- F. To find out if someone has fired a gun or was nearby when it was discharged, scientists analyse gunshot residue (GSR) using a variety of physical and chemical approaches [4].
- G. Data base generation for automated matching and identification purpose. Accordingly the various striation marks present over spent cartridge case and bullets are examined and preserved.

3. Key Technological Advancements

Depending on the nature of case and type of evidence recovered from the crime scene the substantial value of the evidence is determined and accordingly the investigating agency and forensic expert conduct the detailed analysis of the evidence. During the period of time and complex nature of the arms and varying modus operandi, various types of advanced methods are being determined for the examination of the ballistic related case. The various types of advanced method for the analysis are as follows:

- A. **Fingerprint recovery:** Fingerprints on firearm surface can be recovered with cyanoacrylate fuming, also referred to as superglue. Firearms are put within a fume hood that is specially made to disperse fumes rather than remove them. Heat is applied to a container containing liquid superglue to turn it into gas. The fingerprint becomes white as a result of the circulating fumes sticking to the oils left behind by the print.

To make the resulting white print stand out more against the weapon's finish, fingerprint powder can be used to enhance it. Although the fuming process is frequently used on recovered firearms, the textured grip and general state of recovered firearms make it difficult to remove fingerprints from their surfaces.

Integrated Automated Fingerprint Identification System (IAFIS) fingerprint databases can be used to process retrieved fingerprints. A touch DNA test can also be performed on several components of the seized firearm to determine who handled it.

- B. Serial number recovery:** The serial numbers on a recovered weapon may have been changed or destroyed, but examiners can try to find the original numbers. Chemical restoration and magnetic particle examination are the two primary procedures for serial number restoration.
- i. Magnetic particle inspection** - Magnetic particle inspection, a technique that was first created to find faults or anomalies in magnetic materials, can be used on firearms to see the serial number underlying the erased area. Examiners use this method by putting the firearm in a magnetic field. The field deforms due to the imperfections in the metal, in the case of the serial number. A solution of ferrous particles will be drawn to the area where the magnetic field has distorted and will accumulate there when added to the weapon's magnetized surface. UV light can be used to make any recovered serial number easier to see if fluorescent particles are introduced to the ferrous solution.
 - ii. Chemical restoration** - Chemical milling includes processes like chemical restoration. Chemical milling is frequently used to gradually remove material to produce a desired form. Small amounts of metal are removed during serial number restoration until variations in the metal that correlate to the serial number can be seen. This is feasible because the grain boundary structure beneath the metal's surface is altered when the numbers are stamped. Chemical restoration, however, is restricted to that depth and is only effective when the serial number has been obscured relatively little.
- C. Examination of cartridges:** Spent cartridges discovered at a scene can be inspected for tangible proof like fingerprints or compared to samples that identify them as coming from a particular weapon. The firing pin and ejector in semi-automatic and fully-automatic firearms, as well as other elements of the weapon, all leave distinctive tool marks that are used to examine the cartridge. These markings can be compared to known exemplars fired from the same weapon with the same components. A comparison microscope is used to examine the marks left on the cartridge. Looking for matching microscopic markings produced during fire, examiners compare the questioned cartridge to the known exemplar simultaneously.

- D. Examination of bullets:** A preliminary study of the bullet can rule out many different types of weapons by looking at the overall traits of a recovered bullet. Many weapons can be instantly ruled out as being unable to fire that kind of bullet by analysing the general characteristics of the fired ammunition. The combination of various class characteristics that are shared by particular manufacturers can also be used to determine the make and model of the weapon. The lands and grooves, the calibre of the bullet, and the rifling twist are the three key class features of every bullet. The bullet's firing barrel type can be directly linked to all three of these factors. The peaks and valleys formed by the creation of the rifling are the lands and grooves of the barrel. The diameter of the barrel is its calibre. The twist is the clockwise (for right-handed people) or counter-clockwise (for left-handed people) direction of the striations made by the barrel's rifling. With the exception of guns made by the Colt's Manufacturing Company, which feature left-handed twists, the majority of barrels have a right-handed twist.

Examiners must obtain a known sample using the confiscated weapon in order to compare individual striations. By shooting the weapon into a water tank, recognized bullet exemplars are produced for slower-moving bullets, such as those from pistols or revolvers. Since the water slows the bullet down before it reaches the tank walls, the spent bullet can be recovered intact.

Once a known exemplar has been created, the evidence sample can be examined alongside the known under a comparison microscope to be compared to it. Striations that line up are looked at more carefully to see if there are several consecutive matches.

An examiner's training and experience will determine how well they can answer that question. Both the prosecution and the defence may cross-examine examiners over any findings during their testimony in court.

- E. Striation databasing:** In order to identify a firearm from bullets and casings discovered at a scene, a known example must be used as a comparison. The striation pattern can be entered into a database like the National Integrated Ballistic Identification Network (NIBIN) run by the ATF or the National Ballistics Intelligence Service (NABIS) of the United Kingdom even in the absence of a weapon. These databases' information can be utilized to track gun crimes and connect related offenses. These databases' administrators advise that each recovered firearm be tested before the known exemplar is placed into the database. Two databases were established in the 1990s for the storing of images of bullets and shell casings used in firearms crimes.

The FBI used the Drug Fire system, which was the first. The second was developed by Forensic Technology, Inc. and eventually purchased by Alcohol, Tobacco, and Firearms (ATF) in 1993. It is known as the IBIS (Integrated Ballistic Identification System). The FBI and ATF came to the realization that their systems would not cooperate, therefore they needed to develop a mechanism to exchange information. In an effort to develop a single imaging system, the NIBIN board was established in 1997. After the NIBIN board was established, the ATF and FBI decided to pool their resources to develop one of the systems. As a result, they established the National Integrated Ballistics Information Network, with IBIS as the system [2].

The data acquisition station and the signature analysis station are the two components that make up the IBIS instrument. At the data acquisition station, optical microscope images of the breech face, firing pin, or ejector mark are captured under controlled lighting conditions. Next, the acquired image of the specific tool mark is compared with photos in a pertinent database, frequently NIBIN, by the correlation algorithm of the signature analysis station. A correlation score is assigned to each set of photos based on how similar they are to one another. A list of prospective candidates in descending order by determined score is the ultimate result. The examiner can then affirm or deny these findings in order to reach a judgment [5] .

F. Gun Shot Residue (GSR) analysis techniques: Ballistic gunshot residue (GSR) analysis is frequently carried out to ascertain whether a suspect handled a weapon and/or to calculate a firing range. The palms and outside sides of the hands, as well as the tissue supports of the shoulders, hair, and sleeves, are used to collect the GSR samples.

i. Scanning electron microscopy coupled with X-ray microanalysis (SEM/EDX):

A spectral technique known as scanning electron microscopy coupled with energy-dispersion X-ray (SEM/EDX) allows for the visual identification (morphological data) of mineral particles of powder residue left over from primer firing that are mostly made of lead (Pb), barium (Ba), and antimony (Sb). Additionally, the analytical study identifying the elemental composition serves as a second identification to validate the significant presence of the mineral particles cortege of ballistic gunshot residue. Scanning electron microscopy with X-ray microanalysis (SEM/EDX), which is non-destructive and enables the chemical and morphological identification of mineral particles, is always

- preferred for the analysis of gunshot residue of an inorganic nature [6].
- ii. Near-infrared (NIR) Raman micro-spectroscopy - Gunshot residue (GSR) particles from various caliber ammunition are distinguished using near-infrared (NIR) Raman micro-spectroscopy and sophisticated statistics. The way a gun discharges is comparable to a complex chemical reaction. The ammunition, weapon, and cartridge case are all chemical representations of the reagents used in this process. The conditions of the reaction and, consequently, the end result, GSR, are determined by the particular firearm characteristics. It is discovered that the Raman spectra obtained from these goods are typical for various calibers of ammunition. The ability of confocal Raman micro-spectroscopy for the discrimination and identification of GSR particles is demonstrated using GSR particles from 9 mm and 0.38 caliber ammunition, collected under identical discharge conditions. This technique should significantly improve the effectiveness of crime scene investigations when it is completely developed [7].
 - iii. Scanning laser ablation ICPMS and Raman micro-spectroscopy - For the detection and identification of chemicals consistent with gunshot residue particles (GSR), a technique based on Scanning laser ablation inductively coupled plasma-mass spectrometry (SLA-ICPMS) and Raman micro-spectroscopy has been devised. The technique has been used to characterize particles produced when weapons discharge lead-free ammunition. The inorganic and organic residues from skin surfaces were collected in a single sample using modified tape lifts. Aggregates like Cu-Zn-Sn, Zr-Sr, Cu-Zn, Al-Ti, or Al-Sr-Zr, which are consistent with the composition of the ammunition and can only be found in lead-free ammunition, were found using SLA-ICPMS. Micro-Raman spectroscopy added to the evidence by identifying the distinctive organic groups of the particles as centralite, diphenylamine, or their nitrated counterparts, which are indicative of GSR [8].
 - iv. Neutron activation analysis (NAA) - For a number of the elements that can be found in inorganic GSR, neutron activation analysis (NAA) has been used as a bulk analytical technique. The two major elements recognized by this approach are Ba and Sb. However, analysis has also been done on Cu and Au, Ag, Ni, and Co. The trace elements found in the lead core and jacketed bullet fragments were examined by NAA. As many as 13 trace elements could be examined using this technique. The determination of firing distances and the assessment of shooters' hands' GSR have both been done using NAA.

- v. Atomic absorption spectrometry (AAS) - It has been reported that conventional atomic absorption spectrometry (AAS) is sensitive enough to find Pb in GSR samples. Flameless AAS is now appropriate for the detection of Ba and Sb in GSR samples thanks to the development of electro thermal atomizers (carbon rod, tantalum, and graphite tube furnace). The most typical method for collecting samples is with cotton-tipped swabs and 5% nitric acid. Due to its affordability and accessibility, flameless AAS has been described as a successful approach for the analysis of inorganic GSR. It has a benefit over NAA in that it has great sensitivity for Ba and Sb and can be used to find other interesting elements, such Pb. Based on the concentration patterns of Pb surrounding bullet holes, AAS has been used to determine firing distances and to identify GSR on collecting swabs collected from hands by determining the concentrations of antimony and barium.
- vi. Gas chromatography - The most widely utilized detector for organic gunshot residue analysis has been TEA, which has been employed in combination with gas chromatography and a variety of detectors, including flame ionization, electron capture, and mass spectrometry.
- vii. High performance liquid chromatography (HPLC) - HPLC has been applied to the analysis of organic gunshot residue with various detector. NG, 2,4-DNT, and DPA have been analysed with electrochemical detection.
- viii. Capillary electrophoresis (CE) - An essential analytical method known as CE can quickly and accurately separate complicated mixtures. Micellar electrokinetic capillary electrophoresis (MECE), a technique that can separate electrically neutral molecules like those found in OGSR, is an alternative to traditional CE.
- ix. Tandem MS/MS – Highly selective and sensitive method for quantitative analysis of DPA and its nitrated derivatives in smokeless gunpowder. . Detection limits for DPA, N-NDPA, and 4-NDPA were 1.0, 0.5, 2.5 ng/mL, respectively.
- x. Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS) - When analysing smokeless and black powders (and black powder replacements), TOF-SIMS is used to analyse both organic (such as EC, Dibutyl phthalate, and NC) and inorganic (Such as potassium nitrate, potassium perchlorate, and Sulphur) substances. However, it was noted that the approach was inadequate for more volatile components like NG due to the high vacuum inside the instrument.

- xi. X-ray micro-fluorescence has been reported as an applicable method for the analysis of inorganic GSR [9].
 - xii. Integrated Ion Beam Analysis (IBA) - For GSR samples, IBA possesses unheard-of characterization and discrimination power. IBA has the ability to detect elements at much lower levels than is currently possible with SEM-EDS. Additionally, we can relocate particles that have already undergone SEM-EDS analysis using a standard forensic procedure and provide additional information on samples to infer the source of particles found on a suspect, particularly when HMF primers are used. The suggested IBA approach is the only one now available that will allow identification of light elements such as B and Na in GSR particles in addition to trace elements[10].
 - xiii. Marker Based Technique: Luminescent indicators are being identified which can bind up or mixed with the propellant charge which in turn can be used as an gunshot indicator, when the target area and shooter's hand is viewed under specific wavelength of light. The similar technique can be used as a marker's against the specific ammunition which can in turn help to identify the firearm in forensic investigation [11].
- G. Laser-Induced Breakdown Spectroscopy (LIBS)** - The multi-element analysis of the sample is provided using Laser-Induced Breakdown Spectroscopy (LIBS), which requires very little material and no sample preparation. Due to these benefits, LIBS imaging has a significant potential for the viewing of GSR patterns. Two spectrographs with ICCD cameras were utilized in simultaneously with a motorized stage in a LIBS setup. This setup enables the simultaneous detection of the three distinctive elements (Pb, Sb, and Ba) of GSR particles from conventional ammunitions by acquiring information from two different wavelength ranges (258-289 and 446-463 nm) from the same laser-induced plasma. The capacity of LIBS to show the 2D distribution GSR pattern may have significant applications in the field of forensic science, particularly in the field of ballistics [12].
- H. Automated firearms identification (AFI) system** - By comparing various pieces of evidence, such as cartridge cases and bullets, and by identifying similar ones that were shot from the same weapon, AFI systems help shed light on criminal events. A system for automatic picture analysis and identification can quickly assess and categorize ballistic evidence. It can also be used to limit the range of potential supporting evidence. The firing pin impression, capsule traces, and the intersection of these traces on cartridges ejected from the examined pistol were compared automatically using the

image analysis and identification system through the correlation ranking method to establish the numerical values that denote the significance of the similarities. These numerical characteristics that represent the similarities and differences between the makers and models of pistols can be used to classify the different makes and models of pistols [13].

4. Policy Recommendations

4.1 Data Management and sharing - Integrated ballistic information system (IBIS) database has been in place for few years at CFSL, Chandigarh with correlation e-server and data acquisition station; the interacting ones are two CFSLs (Hyderabad and Kolkata) and one State FSL (Mumbai) that have data acquisition station. Gujarat State FSL has its own full-fledged IBIS set up but without any obvious co-participant. Ways and means should therefore be devised to invite all the State / UT FSLs and introduce them to the joy of active participation in pooling & sharing of ballistic data with the nodal base at CFSL Chandigarh. The nodal base CFSL Chandigarh should cooperate globally for cross border data sharing among countries.

4.2 Quality Control and Standardization - Procedures and processes in forensic practice need to be a blend of expertise, experience, excellence and advancement, to render quality service and garner global credibility. Therefore the following are recommended.

- e) There should be discipline wise Scientific Task Forces (STFs) in the lines of Technical Working Groups (TWG) / Scientific Working Groups (SWG), to deliberate and bring out Standard Operating Procedures (SOP) / Manuals. Such exercise should naturally take care of application of recent S&T developments in evidence search / location/ collection / analysis and court testimony; for example: kits, robots, high – throughputs, automation, video teleconferencing. STFs should also review and revise such documents (already in use as well as those forthcoming for new and emerging areas) every three years, so that Good Laboratory Practice (GLP) prevails.
- f) There should be mandatory Certification (and quadrennial recertification) of forensic professionals.
- g) Every forensic laboratory should be accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL) accompanied by the stipulated upkeep and surveillance.

4.3 Research and Development Funding - Research is founded on aptitude, focus, sacrifice and perseverance; then come motivation, incentives and awards.

Researching should be a passion and a habit. Recommendations for reorienting forensic R&D are as follows.

- e) Encouragement should be given to every forensic scientist (and team) to pursue case work hyphenated R&D, intramural innovative R&D and PhD – guiding R&D; such researchers should also bring in R&D project money from outside through international and national funding agencies.
- f) Cash awards should be introduced on every publication in international journal by the scholars.
- g) Exclusive budget provision for foreign travel should be earmarked to enable its employees and research fellows chair sessions, deliver talks and present research papers at scientific meetings.

4.4 Interdisciplinary Collaboration –There should be measures to increase the level of awareness among forensic users (judiciary, police etc.), such as:-

- h) Awareness courses at universities, CFSLs, judicial academies, police academies, directorates of prosecution and bar council.
- i) Forensic participation in zonal, state and national police duty meets.
- j) Regular mailing of (CFSLs' in-house) newsletters to the forensic customers.
- k) Inviting their scripts for inclusion in such newsletters
- l) Inviting their informal participation in CFSLs' monthly journal club meetings.
- m) Vibrant deliberations at meetings of the CFSLs' forensic stakeholders' consultative committees.
- n) All the Central forensic establishments have been accredited by NABL; State / UT forensic establishments should also fall in line immediately.

5. Capacity Building and Training:

Introduction of firearm database nationwide proposed, can be used for matching ballistic information is one of the key measures in the fight against misuse of firearms, and this key measure can uncover numerous connections between firearm related crime scenes. Like INTERPOL has its Firearm reference table. With this effort we can also create an online interactive tool used to provide a standardized methodology to identify and describe firearms. Through this association the nation can create professionals and arrange training to exchange of information, methods and best practices. Regular Trainings to forensic experts can improve knowledge and confidence building in framing opinion on the base on the similarity of marks and variability of marks from same firearm.

Use of 3D technology will provide a statistical foundation for more reliable identification of origin from bullets and cartridge cases. The development of database and trainings would lead to capacity building to foster the development validation of methods and quantitative limits for objective firearm identification.

6. International Cooperation

Firearm tracking and by implementing tracing activities, investigators can make use of various tools available at international level to support international tracing of firearms viz. Illicit Arms Records and Tracing Management System (iARMS) and eTrace. National and International framework for firearm identification can be cooperated to establish national points of contacts on matters related to the protocol and form joint investigative teams for evidence mechanism. The objective of this cooperation would be to maximize the efficiency of investigative resources of two or more jurisdictions through real time information.

Conclusion

Forensic Experts can determine whether the bullet or cartridge case recovered from crime scene was fired from suspect weapon or not. But in some cases the marks may be altered or bullet deformation may lead to false or inconclusive interpretation. Looking into the crime committed in which the firearms are involved emphasis are laid on development of database. Also, this would help to curb the illicit use of firearm and tracking of illegal firearms. Optimum use of scientific examinations and applying advance technologies viz. nanotechnology, 3D imaging etc may express or aid forensic experts to imply about its reliability. Information availability may improve the chances to identify the firearms, save of time, reduce redundant database. International and National firearm database on agreed standards may ensure information and movement across state and territory information.

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Chapter 13

DNA

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1. Introduction

DNA forensics also referred to as DNA profiling or DNA fingerprinting, has had a profound impact on modern law enforcement and criminal justice systems. This technique was pioneered by British geneticist Alec Jeffreys in the mid-1980s (Gill et al., 1985). He discovered that DNA has repeated sequences, which he called “mini-satellites” or “Variable Nucleotide Tandem Repeats (VNTRs)”. These mini-satellites exhibited a high degree of polymorphism among individuals. Jeffrey realized that these characteristics of mini-satellites can be used for individual identification. Thus, he developed the concept of “DNA fingerprinting” as a way to identify individuals based on these mini-satellites. The first case which was resolved by DNA fingerprinting was the “immigration dispute case” of a boy in the United Kingdom in 1985 (Jeffreys, 2005). In 1986, DNA fingerprinting was used for the first time in a criminal case (Enderby murder case). In this case, two-school girl had been raped and murdered in Leicestershire, England. Jeffreys and his team were able to show that a prime suspect’s DNA profile did not match crime scene evidence’s DNA profile. Thus, the first use of DNA in a criminal investigation led to the establishment of innocence, not guilt.

During the last three decades, the technology of DNA Fingerprinting has evolved from early mini-satellite-based Restriction Fragment-Length Polymorphism (RFLP) analysis to Short Tandem Repeats (STR)-based multiplex profiling (Butler, 2012). Short Tandem repeats (STRs) microsatellites or simple sequence repeats (SSRs) are tandemly repeating DNA sequences with repeat units 2-7 base pairs (bp) throughout the human genome, which are polymorphic in nature

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(Butler, 2012; Ruitberg, 2001). In the entire journey of DNA Fingerprinting, the key principles remain the same: (i) Law of individuality: the DNA of every individual is unique (ii) Locard's principle of exchange: whenever any two entities come in contact with each other they leave traces (iii) Parental inheritance: Each individual DNA is inherited from both the parents.

1.1 Significance of DNA Forensics

In India, DNA fingerprinting was first used in 1989 to solve parental dispute cases (Jayaraman, 1989). Since then, DNA technology has been used not only to resolve paternity and maternity cases but also to establish individual identity in various criminal cases and for wildlife forensic identification.

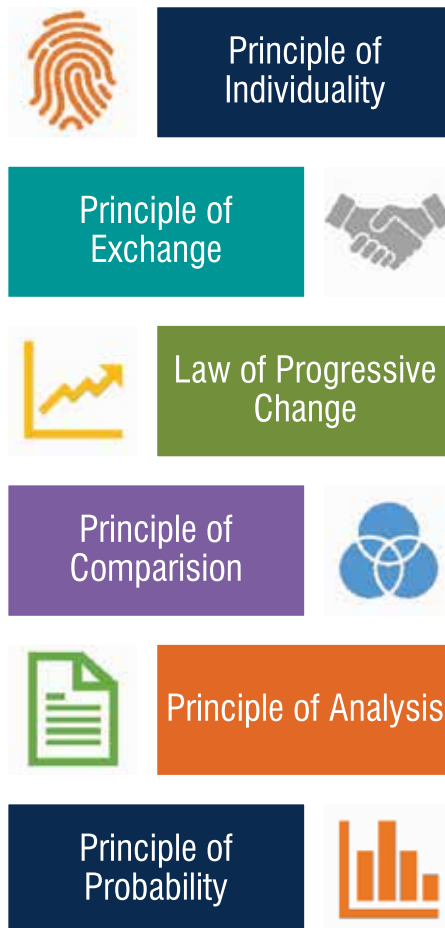


Figure 1. The key principles of DNA Fingerprinting in Forensics

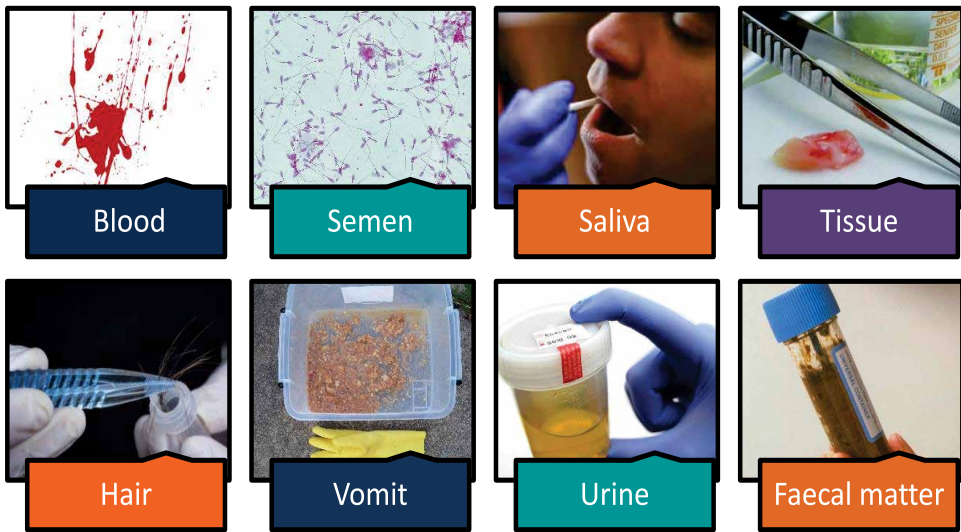


Figure 2. Biological evidences encountered at a crime scene

1.2 Individual identification

DNA fingerprinting is mostly associated with individual identification. It is used to match DNA samples collected from crime scenes (such as blood, hair, semen, or saliva) to potential suspects, victims, or reference databases of known individuals. This aids in identifying perpetrators, linking crimes, and exonerating innocent individuals. This highlights the technology's role in promoting justice and preventing miscarriages of justice.

Paternity and maternity dispute

DNA fingerprinting is used for paternity testing or maternity testing to determine the biological parent of a child. Since the child inherits its DNA from both the parents. It can also be used to confirm relationships in cases of adoption, immigration, or inheritance disputes.

1.3 Sexual assault cases

DNA samples can be found in bodily fluids (such as semen, saliva, and blood) and skin cells left behind during the assault. Forensic laboratories analyse the DNA samples collected from the victim and the crime scene. The primary purpose of DNA evidence is to identify a suspect and/or to demonstrate sexual contact. The presence of spermatozoa on the survivor's body and genital swabs is considered as absolute positive evidence of sexual assault.



1.4 Missing Person and Disaster Victim Identification

DNA profiling is crucial for identifying missing persons and unidentified human remains, such as those resulting from accidents, disasters, or crimes. By comparing DNA from unidentified remains to DNA samples from relatives or databases, law enforcement agencies can provide closure to families and resolve cases.

1.5 Cold-case resolution

DNA profiling has revitalized cold case investigations. Even if a case has gone unsolved for years, preserved biological evidence can be re-analyzed using modern techniques, potentially leading to the identification of previously unknown suspects.

1.6 Genealogy and Ancestry Testing

DNA profiling has become a popular tool for tracing ancestral origins and constructing family trees. This approach combines traditional genealogy research with DNA analysis to uncover family history and identify relatives.

1.7 Investigative Genetic Genealogy

The genealogical aspect can be explored for tracing the paternal lineage for forensic purposes. If the suspects are not available, investigative genetic genealogy can be utilized for tracing the biogeographic location.

1.8 Wildlife Conservation and Environmental Studies

DNA fingerprinting is employed in wildlife forensics to combat illegal trade and poaching. By analyzing DNA samples from animal products, law enforcement can identify the species, origin, and illegal trade routes, aiding conservation efforts.

Broad spectrum of applications of DNA Forensics has been perceived over the years and is an ever-expanding horizon, including human forensic science, diagnostic medicine, family relationship analysis, animal and plant sciences, and wildlife forensic science. Though not restricted to but a few of the broad applications of DNA Forensics can be summarized below:

- To solve paternity problems
- To establish family relationships for immigration
- To identify the offender in rape & murder cases

- To exonerate persons wrongly accused of crimes
- To identify mutilated bodies from tissue remnants
- To maintain social security record
- To identify unknown dead body
- To identify the true parents of the trafficking minors
- To identify the exchanged babies in hospitals
- To identify the people who died in mass disaster
- Genetic Genealogy
- To match organ donors with recipients in transplant programs
- To identify endangered and protected species in wildlife poaching cases
- To determine the pedigree for plant seeds or livestock breeds.

1.9 DNA Profiling and the Indian Legal System

DNA technology has been developed for more than three decades. Several prominent cases of rape and murder have been successfully solved by DNA profiling e.g., the assassination of former Prime Minister of India Shri Rajiv Gandhi, the Tandoor case (Naina Sahani murder case), Priyadarshini Madoo case, the Nirbhaya Rape case (which leads to several legal amendments) and murder of Mr Beant Singh (former Chief Minister of Punjab, India). DNA profiling has always been an integral part of criminal investigation. Still, the criminal justice system has not effectively used the robustness of DNA technology to its full potential. The possible reasons could be inadequate infrastructure facilities during the early stages of DNA profiling, high cost of DNA testing, lack of centralized guidelines for sample collection, processing, and analysis of evidence, lack of skilled manpower, inadequate resources, and accreditation of laboratory (Goswami & Goswami, 2018).

The admissibility of the DNA evidence before the court always depends on proper collection, preservation, and processing of biological evidences, and documentation (intact chain of custody) along with good laboratory practices. Such parameters play an important role in convincing judiciary officials and affirming that the integrity of evidence is maintained and is reliable. In India, there is no specific legislation that can provide specific guidelines to the investigating agencies and the court, and the procedure to be adopted in the cases involving DNA as its evidence. In addition, there is no specific provision under the Code of Criminal Procedure (1973) and the Indian Evidence Act

(1872) to manage science, technology, and forensic science issues. Due to the lack of any such provision, an investigating officer must face many problems in collecting evidence (Srivastava et al., 2022). In addition, the credibility of an expert's opinion depends chain of custody maintained by investigating officers.

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2. Current Landscape of DNA Forensics

By relying on provisions in several legislation that allow for indirect authorization of the acquisition of evidence, Indian courts have been enabling the collection and use of DNA evidence in cases in the current scenario. For instance, a wider interpretation of Sections 53 and 54 CrPC permits DNA tests because they deal with the medical examination of the arrested person upon request and the vetting of the accused in the case by a practicing medical expert, respectively. The 2005 modification to the CrPC includes the new Section 53-A clause, which requires a medical professional to examine the rape accused. The scope of the examination includes DNA, hair samples, swabs of semen, blood, and bloodstains. The court herein also has the power to issue directions to the police to collect blood samples and conduct DNA tests for the purpose of further investigation.

Apart from these provisions, the Evidence Act also allows for the admission of DNA evidence though not directly. Section 45 of the Act deals with the opinion of the expert under which the scientific evidence of DNA has been accepted in several criminal cases. Thus, such evidence is regarded as a mere “belief” tendered by an expert. Thus, as far as the legal framework in India is concerned, there is no existing legal provision that authorizes the direct use of DNA sampling for criminal investigations. When it comes to giving judgments based on such evidence, the courts have primarily maintained that the use of DNA evidence must be done keeping in mind the public interest and constitutional mandate.

Every DNA Forensic Laboratory is required to get accreditation from the regulatory board and adhere closely to all regulations for DNA sample collection, storage, testing, and analysis. The national and regional DNA databanks if sanctioned, may receive the collected data. The laboratories will be liable for making sure that their staff members receive the needed training to enhance their expertise in DNA testing, as well as setting up the necessary infrastructure and security measures to prevent sample contamination and effectively interpret the data/DNA profiles. In cases where the matter has not been resolved or a court order has not been issued, it is required that the labs destroy the subject’s samples and notify them. The majority of suggestions for the admissibility of DNA as evidence have largely converged on the following three points:

- i. The collection, packaging, maintenance of the chain of custody, lab analysis, and reporting of results all should take place in accordance with the standardized and approved guidelines.
- ii. DNA typing is done efficiently and reproducibly while adhering to scientific and legal procedures.
- iii. DNA profiling of any individual must not contravene the Common Law Doctrine of Natural Justice (National Research Council, 1996; Verma & Goswami, 2014). The DNA profile evidence should satisfy the court beyond any reasonable doubt for the criminal liability.

2.1 Forensic Science Laboratories in India

Since the British colonial era, Forensic laboratories have been in existence in India. They are now administered in a three-tiered structure of Central, State, and Regional FSLs (CFSLs, SFSLs, RFSLs), with additional district mobile forensic units (MFSUs). Right now, there are 117 functional FSLs in India. Out of which 10 are accredited by the National Accreditation Board for Testing and

Calibration Laboratories (NABL) (Basu, 2019; Kathane et al., 2021).

3. Challenges faced by FSLs

Lack of Budget /Insufficient funding

According to Forensic Science India Report: A Study of Forensic Science Laboratories (2013-2017) by Project 39A National Law University, Delhi, the report states the process of budget approvals, fund disbursement, and expenditure approvals is complex. In addition, directors lack the financial powers to procure and spend on routine equipment and supplies needed for casework, especially in RFSLS. As they are majorly dependent on SFSLs for funds. The central government does not allocate any funds to conduct Research and Development (R&D) in forensic science.

Lack of Skilled Manpower

The process of sanctioning new posts and filling sanctioned posts takes years to complete. This led to an increased workload among scientific officers. Currently, FSLs are hiring contractual scientific staff to reduce workload. Nevertheless, this has led to a decrease in the integrity of work due to a lack of accountability. Lack of regular training for scientific staff does not allow them to learn new skills and technologies.

Lack of Infrastructure

Most of the FSLs have a severe shortage of space for the proper storage of samples at appropriate temperatures. Further, many FSLs do not have separate areas of documentation and processing of samples. Neither do they have proper mechanisms to restrict access to examination areas, which hampers the quality and integrity of evidence.

Quality management

Since accreditation is not a routine part of FSLs, they lack a quality management system. FSLs are aware of the significance of accreditation, but they are unable to commit the time, resources, and personnel to pursuing it. The possible reason to explain this could be a lack of technical advice, funding, and skilled personnel.

4. Challenges faced by Investigating officers

Collection of samples for DNA analysis

In a forensic investigation, samples may be collected from crime scenes or

suspects. Usually, the first responder on a crime scene is a police official. Thus, it is essential to train police officials to identify and preserve potential samples from contamination till a forensic expert arrives at a crime scene. If a police officer is unaware of the stipulation of biological evidence encountered at a crime scene, there are chances that they may contaminate the samples. Swift observation of the crime scene is a must if there are chances of finding a DNA source. The biological samples should be collected carefully from the scene of the crime. While taking samples from suspects/accused, informed written consent is a must; however, if circumstances are such (for crimes involving imprisonment for five years or more), by order of a judicial officer, the sample can be taken. It is essential to define crime categories for which DNA analysis is needed (Dash et al., 2022).

Maintaining chain of custody

Once the sample is collected, proper packaging and forwarding of the same should be done. Maintaining a chain of custody ensures that submitted exhibits are not tampered with and are integrated to be presented in a court of law (Evans & Stagner, 2003). Due to India's climate, the sample condition at the time of collection may vary across the country. Thus, each laboratory should develop and standardize its protocol, keeping in mind the climate of that geographical location.

Awareness and centralization of kits in DNA evidence processing

A centralized system is yet to be developed to bring synchronization in data generation across India for generating DNA profiles. Certain cases require a certain lookout for the kit processing. Currently, only two to three major companies are catering to the need for kits for DNA profiling (Butler, 2015). Such cases involve data generation using autosomes or Y chromosomes. However, the need for increased high fidelity, proficiency, and power of discrimination is the need of the hour.

Delayed processing of the samples

In certain cases, delay puts a question on the credibility of the evidence being submitted to the court of law. The conditions in which the sample is stored, play a key role in determining the quality of the sample, therefore, the quality of the DNA profile being generated.

Question on improper handling of the evidence

It is crucial that the sample is collected cautiously from the crime scene to avoid breaking the chain of custody. Improper handling can lead to degradation and thus, decrease the credibility of the evidence submitted.

Inconsistency in reporting due to location-specific standardization of laboratories

Depending on the laboratory's location, the protocol's standardization differs based on the climatic conditions. Different climatic conditions require different sample processing strategies, which should be determined by the laboratory's developmental validation

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5. Key Technological Advancements

Science constitutes a perpetually advancing discipline, wherein humanity consistently seeks to enhance current technologies to achieve greater levels of sophistication. Within this context, the realm of forensic science commands particular attention, housing numerous imminent technological advancements. Notably, DNA forensics emerges as a rapidly progressing domain, characterized

by its swift evolution due to groundbreaking innovations in molecular biology. The landscape of forensic science reverberates with ongoing innovation, as various pathways for technological betterment unfold. From the intricate process of sample collection to the nuances of STR profiling, each stage of the DNA analysis workflow represents an arena for continuous refinement and breakthroughs.

It is important to note that human DNA typing, which involves analyzing the genetic material of a single species, has become the established benchmark due to several key factors. These include (a) a collaborative scientific effort aimed at standardizing the specific genetic markers used for analysis, (b) the development of commercially available kits capable of producing consistent results across different instruments and laboratories, (c) the existence of a comprehensive and compatible database that provides allelic frequency data for all human sub-populations, (d) the adoption of standardized statistical methodologies for result reporting, and (e) a substantial body of legal precedents wherein courts have admitted human DNA typing evidence, thereby setting the standard for future cases to rely on such DNA typing results.

5.1 Sample Collection and Processing

i.) Non-Invasive Collection

Advances in non-invasive sample collection have led to techniques that can recover DNA from touch surfaces, such as “swab-less” methods that collect skin cells from surfaces without physical contact.

ii.) Preservation Techniques

New preservation methods, such as paper-based substrates or improved DNA stabilizers, enable longer storage of biological samples at room temperature without significant degradation.

Vacuum Sealing: Vacuum sealing removes air and moisture from the packaging, preventing degradation due to oxidation and microbial growth.

RNA Stabilization Solutions: RNA is notoriously sensitive to degradation. Stabilization solutions can preserve RNA integrity by preventing the activity of RNases (enzymes that degrade RNA).

DNA/RNA Shield Solutions: These solutions stabilize DNA and RNA, allowing samples to be stored at ambient temperatures without degradation for subsequent analysis.



6. Modern Solutions for Chain of Custody

Mobile Applications and Digital Platforms:

Innovations in mobile applications and digital platforms are revolutionizing the evidence collection, tracking, and documentation processes. These technological tools are designed to streamline and digitize these procedures, offering functionalities such as GPS tagging, timestamps, and secure cloud storage.

Barcode and RFID Technology:

Efficient labeling and tracking of evidence items are facilitated by barcode and Radio Frequency Identification (RFID) technology. These systems automate the tracking process, minimizing the risk of errors and enhancing accountability throughout the chain of custody.

Evidence Management Software:

Dedicated software solutions are being developed to oversee the entire chain of custody process. These platforms enable digital documentation, real-time updates, and access control for authorized personnel, ensuring efficient evidence management.

Secure Packaging and Tamper-Evident Seals:

Innovative packaging and sealing techniques play a crucial role in preserving the integrity of evidence during transportation and storage. Tamper-evident seals and secure packaging mechanisms prevent unauthorized access and tampering.

Digital Signatures and Encryption:

The use of digital signatures and encryption methods serves to authenticate documents and safeguard sensitive information within the chain of custody. These security measures ensure the confidentiality and reliability of data.

Blockchain Technology:

The exploration of blockchain technology offers an opportunity to enhance the security and transparency of the chain of custody process. Its decentralized and tamper-resistant nature can effectively safeguard the integrity of evidence documentation.

Geotagging and Geofencing:

Geotagging involves attaching location data to evidence, while geofencing

establishes virtual boundaries. These technologies contribute to the accuracy of documenting evidence collection locations, providing valuable context and information.

7. DNA Extraction:

DNA extraction is a foundational process that involves the separation of DNA from proteins and other cellular components, aiming to obtain DNA in both sufficient quantity and purity for subsequent analytical applications. The historical roots of DNA extraction date back to 1869 when Friedrich Miescher pioneered the process by isolating nucleic acids from leucocytes (Dahm 2005). Miescher's initial approach involved the use of hydrochloric acid, ether, and alkaline solutions, followed by refining the method by employing pepsin for protein digestion.

Over time, DNA extraction methodologies have evolved significantly, enhancing both speed and efficacy. In the contemporary forensic DNA landscape, the process generally consists of three primary stages: (a) cell membrane lysis to release DNA, (b) enzymatic breakdown or denaturation of proteins to free DNA from nucleoproteins, and (c) separation of DNA from cellular constituents and potential inhibitors. While an ideal scenario in forensic DNA labs would involve a single automated method for all sample types, real-world challenges such as high work volumes, sample variety, limited material, degradation, and environmental contaminants necessitate tailored approaches (Ensenberger et al. 2014; Park et al. 2008).

Forensic DNA laboratories encounter a diverse range of samples, each demanding a specific extraction strategy. Crime scene samples require methods effective against inhibitors like humic acid, tannins, and dyes that can interfere with downstream PCR processes. In contrast, reference blood or buccal samples offer simpler extraction processes (Ensenberger et al. 2014; Park et al. 2008).

While numerous extraction methods have been developed for forensic use, the following are the key areas where major innovations are happening.

Solid-Phase Extraction: Solid-phase extraction methods using magnetic beads or silica columns have become standard, offering higher yields and improved purity of extracted DNA.

Automated Extraction: High-throughput automated extraction systems are now capable of processing multiple samples simultaneously, reducing processing time and improving consistency.

Minimizing Inhibition: Novel reagents and extraction kits are designed to minimize PCR inhibitors commonly present in forensic samples, improving the success rate of DNA amplification.

A lot of improved kits are available in the market catering to the needs of forensic experts in the laboratory, especially for different challenging samples like burned tissues/bones, ancient samples, highly degraded samples, isolation of male DNA from sexual assault samples, etc.

8. Isolation of male DNA from sexual assault samples

Differential extraction, also referred to as differential analysis, is a method designed to selectively isolate DNA from distinct cell or tissue types within a mixture. In the field of forensic DNA analysis, this technique finds significant application in the handling of sexual assault evidence. Here, the goal is to segregate male DNA originating from sperm cells, distinct from female DNA sourced from epithelial cells. Notably, achieving complete separation is often challenging due to carryover effects, and the presence of male epithelial cells, compounded by the potential lysis of sperm caused by environmental stressors. It's noteworthy that the DE process might lead to a considerable loss of male DNA during washing steps, with reported rates as high as 90% (Vuichard et al. 2011). To address these intricacies, diverse adaptations to the DE protocol have been proposed in existing literature (Cotton and Fisher 2015) the molecular biology techniques in use today represent significant advances since the introduction of STR testing. Large forensic laboratories with dedicated research teams and forensic laboratories which are part of academic institutions have the resources to keep track of advances which can then be considered for further research or incorporated into current testing methods. However, many laboratories have limited ability to keep up with research advances outside of the immediate area of forensic science and may not have access to a large university library systems. This review focuses on filling this gap with respect to areas of research that intersect with selected methods used in forensic biology. The review summarizes information collected from several areas of the scientific literature where advances in molecular biology have produced information relevant to DNA analysis of sexual assault evidence and methods used in presumptive and confirmatory identification of semen. Older information from the literature is also included where this information may not be commonly known and is relevant to current methods. The topics selected highlight (1. This segment thus aims to outline modifications to the differential extraction procedure,

seeking to enhance male DNA recovery. Additionally, it explores alternative strategies such as sperm capture for improved separation and the integration of automation to expedite the typically time-consuming process. An overview of the varied advanced protocols for male DNA extraction is summarized in Table below.

Table: Advanced protocols for male DNA extraction from sexual assault samples

Protocol	Principle	Major advantage	Reference
Differential extraction (DE)	Use of reducing agent DTT for specific sperm lysis	Good sperm separation efficiency	(Yoshida et al. 1995)
Differex system	combination of phase separation and differential centrifugation to separate sperm from epithelial cells	Less labour-intensive and amenable to automation	(Tereba et al. 2004)
Laser microdissection (LMD)	Microscopy-based sperm detection and collection	Accurate separation of sperm and no carryover of female fraction	(Costa et al. 2017)
Optical tweezer	Optical trapping of Sperm by high density lasers	Less time as compared to LMD	(Auka et al. 2019)
DEPArray system	Dielectrophoretic (DEP) cages to capture and manipulate sperm within a microfluidic cartridge	High sensitivity and specificity	(Williamson et al. 2018)
Antibody i.e. Anti PH-20 on Immunomagneticbeads	PH 20 (specific to sperm head) antibody-based affinity purification approach	Less female carryover as compared to DE	(Shen et al. 2010)
SOMAmer	Slow Off-rate Modified Aptamers (SOMA) having higher affinity to ligand on sperm.	Higher recovery than Antibody based approach	(Katilius et al. 2018)

Protocol	Principle	Major advantage	Reference
SLeX	Sperm capture through Sialyl-LewisX (SLeX) ligand.	Higher affinity with sperms than the antibodies	(Inci et al. 2018)
Promega Maxwell 16 DNA extraction system	(semi)-automate DE to reduce the laborious effort and processing time	It can reduce the DE processing time to only 3 hr	(Ng et al. 2017)
VERSA 1100 Liquid handler system	A more recent semi-automated DE method	Sixfold higher throughput of 96 samples in 8 hr with minimal human intervention	(Karch and Wong 2009)
Hamilton AutoLys STAR system	Fully automatic DE system	Full automation of the DE process after an initial manual loading of the sample into proprietary AutoLys-A tubes	(Timken et al. 2019)

9. Use of automated and portable rapid DNA instruments

Law enforcement's increasing demand for swift forensic DNA analyses has spurred the creation of rapid DNA instrumentation, revolutionizing the process. This technology streamlines all steps involved in obtaining CODIS core loci STR profiles from reference buccal samples within a mere two hours, as endorsed by the FBI. By fully automating procedures such as cell lysis, DNA extraction/purification, amplification, electrophoretic separation, fluorescence detection, and allele calling, this innovation significantly diminishes the need for human intervention, with only sample collection and placement into the instrument remaining as manual tasks. Over time, the potential reduction in labor costs could potentially offset the initial high investment in equipment, maintenance, and consumables.

The genesis of rapid DNA can be attributed to breakthroughs in “lab-on-a-chip” (LOC) and microfluidic technologies, seamlessly integrated with sophisticated DNA profile interpretation software. This symbiotic combination results in an end-to-end process where a sample-in-result-out outcome is achieved sans human interference. At its core, a lab-on-a-chip is an advanced device that amalgamates one or more processes onto a platform outfitted with sensors and electrical components. The magic of microfluidic technology leverages this platform to control the flow of liquids within a network of channels and chambers, enhanced by micropumps and microvalves that meticulously execute sequential procedures.

In the nascent stages of forensic DNA profiling’s foray into LOC devices, these chips could only manage singular or, at most, two to three consecutive steps due to the inherent intricacies of integrating the entire sequence. For example, early iterations predominantly focused on rapidly cycling PCR temperatures, with a reduced volume and cycle duration, yet neglecting aspects like sample lysis. This limitation prompted separate off-chip lysis, but this introduced an elevated risk of contamination, thereby curbing adoption within the forensic DNA community. The details of the two commercially accessible microfluidic rapid DNA instruments are described in the following table below.

Table: Summary of rapid DNA analysis instruments in forensics

Commercial System	Description	Features	Reference
RapidHit ID System	It is a fast and simple-to-use instrument that produces trusted lab-quality forensic DNA profiles in as little as 90 minutes.	<ul style="list-style-type: none"> • Sample to answer in as little as 90 minutes • 1-minute hands-on time with integrated sample cartridge • Consumables tracking through radio frequency identification (RFID) • Intuitive touchscreen interface • Facial recognition and barcode camera • Fingerprint reader • Up to twelve months of shelf life for both sample and primary cartridges • FBI NDIS-approved rapid DNA system and booking station device 	(Amick and Swiger 2019)

Commercial System	Description	Features	Reference
DNAscan/ ANDE rapid DNA analysis system	fully automated, ruggedized, STR analysis system with integrated data analysis and Expert System software.	<ul style="list-style-type: none"> ● It generates STR profiles from Flexplex chemistry, for up to five samples simultaneously, in less than 90 minutes. ● The instrument automatically performs sample-in to results-out STR processing and analysis. ● The integrated Expert System software processes and analyzes data and generates the STR profile output files. ● All reagents are factory preloaded in a disposable “all-in-one” NetBio BioChipSet™ Cassette. ● The NetBio BioChipSet Swab seals and locks into the NetBio BioChipSet Cassette to minimize the potential for cross-contamination. ● The accompanying DNAscan Data Management Software supports integration and management of DNAscan data with laboratory and police station workflows. 	(French et al. 2016)

10. DNA extraction from difficult samples

In scenarios demanding the identification of victims subsequent to natural or human-caused calamities, the forensic DNA laboratory might encounter the challenge of managing blood and soft tissue samples in the initial aftermath of the incident. Over time, decomposition or exposure to high temperatures—such as in fire-related situations—might further complicate matters, leading to the handling of more intricate samples like teeth and bones. In these particular samples, the DNA is intricately linked to the hydroxyapatite mineral matrix, affording it robust protection. However, this protective connection also necessitates prolonged and intensive preliminary processing of samples before DNA extraction becomes viable (Brundin et al. 2013; Latham and Miller 2019).

In instances of human-made disasters, whether accidents or acts of terrorism, samples from casework could potentially be tainted with chemical, biological, or radiological (CBR) agents. Consequently, beyond the routine processing of typical crime samples, forensic DNA laboratories must establish protocols

to effectively manage skeletal remains and unconventional CBR-contaminated samples, ensuring a comprehensive approach to forensic analysis.

(i) Human Remains

The process of victim identification through DNA profiling presents unique challenges when dealing with skeletal and dental remains, primarily due to the inherent difficulty in accessing the DNA within these structures. Nevertheless, these remains can serve as protected reservoirs for DNA, as the genetic material is intricately bonded to the hydroxyapatite mineral matrix, offering it considerable safeguard against degradation (Latham and Miller 2019). Furthermore, skeletal and dental remains often endure even after the decomposition or incineration of soft bodily tissues. The preservation of DNA within these skeletal and dental remains hinges on a complex interplay of environmental factors and the intrinsic characteristics of the remains themselves. In recent years, there has been notable progress in developing novel methods to enhance DNA extraction from challenging remains. For instance, rather than processing the entire tooth, it has become evident that targeted extraction of either the dental pulp or root tip can yield more effective results (Cafiero et al. 2019; Carrasco et al. 2017; Corrêa et al. 2017; Mansour et al. 2018). The harvesting of dental pulp, in particular, has demonstrated a higher DNA yield compared to the traditional approach of pulverization and decalcification, yielding DNA of acceptable quality for subsequent STR and SNP analysis (Cafiero et al. 2019; Carrasco et al. 2017). It's worth noting, however, that the process of dental pulp extraction entails an investment in specialized instrumentation, such as microscopes or X-ray equipment, to ensure precise access to the pulp cavity, along with software analysis and the requisite expertise (Cafiero et al. 2019; Carrasco et al. 2017).

Concerning skeletal remains, bone powders have traditionally been the primary type of bone samples utilized for DNA extraction (Amory et al. 2012; Karija Vlahović and Kubat 2012; Latham and Miller 2019; Zupanič Pajnič and Fattorini 2021). The process of bone pulverization holds significant importance as it maximizes the available surface area for the recovery of DNA from the hydroxyapatite matrix. Notably, recent developments have showcased the effectiveness of the ANDE rapid DNA system in processing contemporary pulverized bone and tooth samples, yielding high-quality profiles within a mere 2 hours (Turingan et al. 2020). Nevertheless, it's crucial to acknowledge that the ANDE rapid DNA system's efficiency remains contingent on the time-consuming bone pulverization process. Consequently, there is a growing desire

for a method that eliminates the need for pulverization while maintaining DNA yield and profile quality. In a recent investigation, DNA recovery from bone chips proved successful when samples were pretreated with the TBone Ex buffer (DiagnoCine) before undergoing DNA extraction with the PrepFiler BTA kit (Thermo Fisher Scientific) (Harrel et al. 2018). Impressively, the quality of DNA profiles obtained from bone chips was on par with those obtained from conventional pulverized bone samples. However, it's important to note that this method presents limitations in terms of its potential for automation to achieve higher throughput and expedited processing (Harrel and Hughes-Stamm 2020; Harrel et al. 2018).

(ii) Biological Agents

Biological agents encompass various infectious pathogens like *Bacillus anthracis* and smallpox (Bronze et al. 2002). DNA extraction for human identification isn't hindered by these agents since the process doesn't distinguish between human cells and microbes (Alessandrini et al. 2019; Socratous and Graham 2008). Pretreatment with detergents, proteases, and subsequent chemical or chaotropic agents releases both human and microbial nucleic acids, rendering the microbes harmless. Forensic DNA labs need protocols for sample collection, transportation, and preprocessing. In biological agent investigations, microbial genotyping can trace the source, as seen in the 2001 anthrax attack in the U.S. (Keim, Budowle, and Ravel 2010). DNA extraction methods work well for bacteria and viruses, except for bacterial endospores. Recent studies show promise in extracting DNA from endospores using mechanical lysis or chemical lysis like sporeLYSE (de Bruin et al. 2019). Liquid reagents may be favored over mechanical lysis for efficiency in forensic DNA extraction. The sporeLYSE method effectively extracts DNA from various bacteria and endospores, with research needed on the DNA quality for genotyping and sequencing in microbial forensics labs.

11. Bypassing DNA extraction

Another major advancement is the contemporary approaches bypassing extraction steps, inspired by colony PCR's direct introduction of a bacterial colony into the PCR mastermix for gene detection. Can forensic samples similarly enter the PCR mastermix for high-quality DNA profiles?

Despite challenges, direct PCR's potential led to various techniques for forensic samples (Ambers et al. 2018; Burns et al. 1997; Fridez and Coquoz 1996;

Kitpipit et al. 2014; Linacre et al. 2010; Lynch and Fleming 2019; Park et al. 2008; Swaran and Welch 2012; Sweet et al. 1996; Templeton and Linacre 2014; Verheij, Harteveld, and Sijen 2012). The fascination with direct PCR amplification has spurred additional innovations. The notion of lysis on a solid substrate followed by PCR amplification emerged in the mid-1980s with direct amplification of reference samples on FTA cards. In recent years, this concept has been harnessed by the French Gendarmerie Forensic Research Institute (IRCGN) and COPAN in the form of the microFLOQ Direct swab. This small swab head, approximately 1 mm in diameter, comprises short nylon fibers infused with lysing agents, enabling *in situ* sample lysis upon collection (Sherier et al. 2020). The swab's shaft includes a breakage point for easy snapping of the entire swab head into a PCR tube for amplification. The minimal sample collected on the swab head allows for targeted collection of minute samples, leaving sufficient biological material for potential re-testing, as there is no DNA loss in extraction or purification steps (Templeton et al. 2015). Studies have shown consistently higher allele peak heights for diluted blood and saliva samples compared to PCR amplification using 1 ng of purified DNA (Ambers et al. 2018). Subsequently, the microFLOQ Direct swab has been applied to various biological samples (Ambers et al. 2018; Chong et al. 2019; Sherier et al. 2020).

Reagents for direct lysis of cells in casework (non-reference) samples have also been developed. The Casework Direct kit, Custom (Promega), contains a buffer and reducing agent to generate PCR-ready lysates from biological stains and touch samples (Hakim et al. 2019). In one study, microFLOQ™ Direct swabs were used for sample collection in conjunction with pre-PCR amplification treatment using the Casework Direct kit, Custom (Sherier et al. 2020). Additionally, Wong et al. 2019 demonstrated that a low TE buffer could serve as a more cost-effective alternative to the Casework Direct kit, Custom for use with the microFLOQ Direct swab.

12. STR Profiling:

Improved STR kits:

The continuous improvement and refinement of Short Tandem Repeat (STR) profiling kits are of paramount importance in the field of forensic science and genetic analysis. These kits serve as essential tools for accurately identifying individuals based on their unique DNA profiles. By constantly improvising

and enhancing these kits, scientists can achieve higher levels of accuracy, sensitivity, and reliability in DNA analysis. This not only aids in solving crimes and identifying individuals in disaster scenarios but also ensures the integrity of the criminal justice system. Additionally, as technology advances and genetic databases expand, staying at the forefront of STR profiling kit development allows forensic experts to adapt to evolving challenges and maintain the highest standards of accuracy and fairness in the judicial process. Table ____ contains the list of the STR kits validated during 2019-2022. In India, all the DNA analysis laboratories are using majorly the following kits.

1. Identifiler Plus (16 markers)
2. GlobalFiler (24 markers)
3. Investigator 24plex QS (24 markers)
4. PowerPlex Fusion 6C (24 Markers)

Table: Recently (2019-2022) developed and validated STR kits

No.	STR Kit	Reference
Autosomal STR Loci		
1	VeriFiler Plus	(Janaahi, Ghafri, and Qamar 2019)
2	SureID 23comp Human Identification	(Alsafiah et al. 2019)
3	DNATyper25	(Mo et al. 2019)
4	Investigator 24plex QS,	(Cho et al. 2021)
5	PowerPlex Fusion,	(Cho et al. 2021)
6	GlobalFiler	(Cho et al. 2021)
7	STRtyper-32G	(Fan et al. 2021)
8	VeriFiler Plus	(Green et al. 2021)
9	Investigator 24plex GO!	(Hakim et al. 2020)
10	Investigator 24plex QS and GO!	(Harrel et al. 2021)
11	STRscan-17LC kit	(Jiang, He, et al. 2021)
12	Novel 8-dye STR multiplex	(Jiang, Qu, et al. 2021)
13	SureID S6 system	(Li et al. 2021)
14	Microreader 20A ID system	(S. Qu et al. 2019)
15	Novel 6-dye, 31-plex	(Y. Qu et al. 2021)
16	21plex with DYS391 and ABO	(L. Wang et al. 2020)

No.	STR Kit	Reference
17	Investigator 26plex QS kit	(S. Wang et al. 2020)
18	Novel 26plex	(Xie et al. 2022)
19	Microreader 28A ID System	(Yin et al. 2021)
20	SiFaSTR 21plex_NCII	(J. Zhang et al. 2020)
21	AGCU Expressmarker 30 Kit	(K. Zhang et al. 2021)
22	SiFaSTR 23-plex panel	(Zheng et al. 2019)
23	Huaxia Platinum PCR kit	(Zhong et al. 2019)
Y-STR Loci Kits		
Combined (Autosomal + Y STRs) Kits		
1	19 autosomal and 27 Y-STRs	(Liu et al. 2020)
2	AGCU Expressmarker 16 + 22Y	(Xie et al. 2020)
3	VersaPlex 27PY system	(Lenz et al. 2020)Europe (ESS)

13. Next-Generation Capillary Electrophoresis:

Despite DNA forensics being a field with a 35-year history, the market has been relatively limited in terms of available capillary electrophoresis instruments. Until 2020, Applied Biosystems' genetic analysers (a few different models based on the throughput) stood as the sole commercial option. However, a noteworthy development occurred when Promega introduced their genetic analyser instrument named Spectrum. Both manufacturers are committed to ongoing refinement and innovation of these machines, aiming to achieve the utmost precision and automation in DNA analysis. As described in Table below, these modern capillary electrophoresis instruments provide higher resolution and sensitivity for STR analysis, enabling the detection of minor contributors in mixed samples.

Table: Features of next generation genetic analysers

Features	SeqStudio	SeqStudio Flex Series	Applied Biosystems 3500 Series	Applied Biosystems 3730 Series	Spectrum CE System
Number of capillaries	4	8 or 24	8 or 24	8 or 24	48 or 96
Capillary array length (cm)	24	36 or 50	36 or 50	36 or 50	36

Features	SeqStudio	SeqStudio Flex Series	Applied Biosystems 3500 Series	Applied Biosystems 3730 Series	Spectrum CE System
No. of Dyes	6	8	6	6	8
Sample re-prioritization	No	Yes	Yes	No	Yes
Remote monitoring and data sharing	Yes	Yes	No	No	Yes
Connectivity	Connect cloud-based platform; USB port for Wi-Fi dongle; 3 RJ-45 ethernet ports	Connect cloud-based platform; USB port for Wi-Fi dongle; 3 RJ-45 ethernet ports	Ethernet port	Ethernet port	USB, Cloud, Ethernet port

14. Improved Analytical Software:

DNA forensics encompasses distinct segments, each yielding specific data types necessitating dedicated software for analysis. Within this domain, three distinct sections demand specialized software or computer management systems:

i. STR Raw Data Processing Software:

This software is dedicated to the processing of raw data derived from Short Tandem Repeat (STR) profiling. It plays a crucial role in interpreting and generating DNA profiles for individual identification. Much like any analytical procedure, capillary electrophoresis instruments generate raw fluorescence data. The resulting DNA files from a Genetic Analyzer will typically bear one of three extensions: .fsa, .hid, or .promega, contingent upon the specific instrument employed to gather data from PCR-amplified STR markers. Notably, .fsa files, denoting “fragment size analysis,” are generated by ABI 310, 3100, 3130, 3700, and 3730 series CE instruments, while .hid files, known as “human identity,” originate from ABI 3500 series CE systems. The .promega file type is exclusive to Promega’s Spectrum CE System.

In tandem with instrumental advancements, sophisticated software has been developed to expedite the STR genotyping process by swiftly processing

electrophoretic data. These software algorithms have continuously evolved, progressively enhancing the sophistication and precision of STR analysis. Currently, the GeneMapper ID-X v1.6 (Applied Biosystems) and GeneMarker®HID Software (Promega) are the choice for the analysis of STR data.

ii. Mixture Profile Analysis Software:

The task of deciphering mixed DNA profiles extracted from forensic evidence materials represents one of the most intricate responsibilities faced by forensic scientists. Historically, analysts employed a “binary” interpretation approach, where inferred genotypes were either deemed as part of or excluded from the mixture based on stochastic thresholds and additional biological criteria, including factors like heterozygote balance, mixture ratio, and stutter ratios. Over the past quarter-century, advancements in the sensitivity of Short Tandem Repeat (STR) multiplexes and capillary electrophoresis equipment have significantly improved. Concurrently, there has been a shift in the nature of evidence submitted for analysis – transitioning from high-quality and high-quantity stains, often of single-source origin, to low-quality and low-quantity “touch” samples, frequently comprising mixed DNA profiles. This shift has brought about a commensurate escalation in the complexity of DNA profile interpretation. As reviewed by Coble and Bright (2019), the first appearance of the concept of probabilistic genotyping was in 2001 (Gill et al 2000). This paper introduces a probabilistic methodology for integrating probabilities related to dropout, drop-in, and stutter into the Likelihood Ratio (LR) statistic.

In broad terms, probabilistic genotyping software can be categorized into two primary types: semi-continuous and fully continuous methods. The semi-continuous approach, also referred to as the drop model or discrete model, provides the option to incorporate probabilities for dropout ($\text{Pr}(D)$) and/or drop-in ($\text{Pr}(C)$). Notably, semi-continuous methods refrain from utilizing peak heights when generating potential genotype sets and do not model artifacts like stutter. However, it's important to note that one limitation of semi-continuous methods is their partial utilization of peak height information. Peak heights play a crucial role for end-users of the software, assisting in the determination of parameters such as the likelihood of dropout or the identification of the number of contributors within the mixture. Forensic laboratories have notably embraced probabilistic genotyping systems for the interpretation of mixed DNA profiles in recent times. The table below describes the validated probabilistic mixture interpretation software.

Table: List of probabilistic genotype analysis in DNA forensics

Software	Link	Free/Open Source/ Commercial	Reference
Semi-continuous Software Solutions			
Lab Retriever	(https://scieg.org/lab-retriever/)	open source	(Inman et al. 2015)
LRmix/LRmix Studio	http://www.lrmixstudio.org/	open source	(Gill and Haned 2013)
Fully-continuous Software Solutions			
LikeLTD	https://cran.r-project.org/web/packages/likeLTD/index.html	open source	(Steele, Greenhalgh, and Balding 2014)
TrueAllele	https://www.cybgen.com/	Commercial	(Perlin and Sinelnikov 2009)
GenoProof Mixture	https://www.qualitype.de/en/solutions/products/evaluation-software/geno-proof-mixture/	Commercial	
EuroForMix	http://euroformix.com/	open source	(Bleka, Storvik, and Gill 2016)
STRmix	https://strmix.esr.cri.nz/	Commercial	(Taylor, Bright, and Buckleton 2013)
Kongoh	https://strmix.esr.cri.nz/	Commercial	(Manabe et al. 2017)
MaSTR	https://www.softgenetics.com/MaSTR.php	Commercial	
DNA-View Mixture Solution	http://dna-view.com/	Commercial	http://dna-view.com/downloads/Mixture%20Solution%20poster.pdf
DNAmixtures	http://dnamixtures.r-forge.r-project.org/	Open source (The DNAmixtures program is freely available, but requires the commercially available software program HUGIN to operate)	(Cowell et al. 2015)

Software	Link	Free/Open Source/ Commercial	Reference
CeesIT	https://lftdi.camden.rutgers.edu/provedit/software/nocit-ceesit-academic-and-research-license/	Free	(Swaminathan et al. 2016)
LiRa HT	https://cdnmedia.eurofins.com/european-west/media/1418957/lgc_lira_fact_sheet_en_0815_90.pdf	Commercial	(Puch-Solis and Clayton 2014)
eDNA	http://ednalims.com/probabilistic-genotyping/	Free web-based software* (*Two software programs, Bullet (Semi-continuous) and BulletProof (Fully-continuous) are available to members with subscriptions to their service. Bullet uses the internal maths of LRmix, and BulletProof uses the internal maths of EuroForMix. Each program has a custom graphical user interface.)	http://ednalims.com/probabilistic-genotyping/

iii. DNA Database Management Software:

DNA database management software is indispensable for the efficient storage, retrieval, and management of DNA profiles obtained from various sources. It plays a pivotal role in maintaining organized and accessible forensic databases.

Software applications designed for the management and comparison of DNA profiles are commonly referred to as DNA database software. These programs can serve various functions beyond mere storage and comparison. DNA database software may originate from internal development efforts by a country to address its specific requirements, or it can be obtained from developers, either as free offerings or through commercial arrangements. Notable examples



of DNA database programs available without cost include:

CODIS: Originally developed by the FBI for use in the United States, CODIS is accessible to law enforcement organizations outside the USA as well. A private company, ECS Tech (formerly Leidos), administers a proficient helpdesk, and computer-based training resources are readily available. CODIS offers three tiers for storing and comparing DNA profiles: local, state, and national, facilitating data integration at all levels with secure framework. The software can be obtained from FBI through government-to-government requisition.

The CODIS has been installed in India at Center for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad for the analysis of human remains of Uttarakhand disaster during 2013.

GENis: Argentina has independently developed its own DNA database program named GENis, which operates as an open-source system capable of managing forensic DNA databases at local, regional, and national levels.

Additionally, there are commercially available DNA database software programs, including:

- **FSS-iD:** Originally from the Forensic Science Service in the United Kingdom.
- **Dimensions:** Developed by the Austrian company Ysselbach Security Systems.
- **eQMS: DNA:** Offered by the Croatian company Pardus.
- **fDMS-STRdb:** Distributed by the Czech Republic-based company Forensic DNA Service.
- **RapidDNA:** Developed by the Australian company Forensics International.
- **SmallPond:** Commercially available at SmallPond's website.
- **Bode Match:** Commercially accessible through Bode Cellmark's website.

These diverse DNA database software solutions cater to the varied needs of forensic laboratories and law enforcement agencies, with options ranging from open-source systems to commercially supported platforms.

15. Microfluidic Systems

Lab-on-a-chip and microfluidic platforms offer rapid and efficient STR analysis, using nanoliter volumes and allowing for faster separation of DNA fragments. The details of two commercial platforms are previously explained earlier.

15.1 Other Emerging Advanced Technologies

Continual advancements in forensic DNA typing technologies are in progress. In this section, we delve into recent developments in next-generation DNA sequencing, DNA phenotyping for estimating characteristics such as age, ancestry, and appearance of sample donors, lineage markers, alternative markers and methodologies etc. This information is intended to provide insights and guidance to practitioners as they explore the future directions and possibilities within the field.

16. Massively Parallel Sequencing (MPS)

Next-generation sequencing (NGS), commonly referred to as massively parallel sequencing (MPS) within the forensic DNA community, represents a significant advancement in DNA analysis. MPS enables simultaneous sequencing of multiple DNA fragments, aiding in the analysis of degraded samples and mixed DNA. It also provides insights into identity, ancestry, and phenotypic traits. It surpasses the conventional length-based results achieved through capillary electrophoresis (CE) methods by expanding the measurement capabilities and information content of a DNA sample. NGS enables the analysis of additional genetic markers, including single nucleotide polymorphisms (SNPs), microhaplotypes, and the sequencing of the entire mitochondrial genome (mtGenome), in conjunction with the full sequence of Short Tandem Repeat (STR) alleles. This heightened information richness per sample paves the way for novel applications, such as the determination of externally visible characteristics and biogeographical ancestry, as extensively discussed in review articles (de Knijff 2019; Ballard, Winkler-Galicki, and Wesolý 2020). Emerging sequencing techniques encompass a range of diverse technologies, including sequencing by synthesis (SBS) involving clonal nucleic acid amplification (Ronaghi, Uhlén, and Nyrén 1998), nanopore sequencing (Jain et al. 2015), and real-time single molecule sequencing (Rhoads and Au 2015). While it's important to note that MPS (massively parallel sequencing) platforms exhibit error rates higher than those of Sanger sequencing, ranging from 0.5% to 15% depending on the specific platform employed, this limitation can be effectively mitigated through meticulous experimental design, particularly by ensuring adequate sample coverage (Ballard, Winkler-Galicki, and Wesolý 2020).

17. Body Fluid Identification

Detecting specific body fluids is crucial in investigations, offering insights into

incidents, especially when linking a DNA profile to a biological source. Current tests for some body fluids have limitations, necessitating multiple tests that can deplete samples [52]. RNA analysis alongside DNA is gaining interest for its potential to identify body fluids. RNA varies by cell type, making it tissue-specific. Large-scale screenings and PCR-based assays, like RT-PCR and RT-qPCR, are used for identifying body fluids, with MPS becoming more popular [56–59].

Initially, mRNA markers were explored, but their susceptibility to degradation limited forensic use. Micro RNAs (miRNAs) are now gaining attention as more stable alternatives. miRNAs target mRNA for degradation and show tissue-specific expression. Panels of differentially expressed miRNAs are being used to identify specific body fluids [67–73], though challenges remain, especially in interpretation. Further research to pinpoint the best miRNA sets for precise body fluid identification and rigorous validation could provide a reliable forensic test [65]. miRNA markers also hold potential for estimating deposition time [74,75] and post-mortem intervals [76].

18. Epigenetics in Forensics

In addition to the genomic DNA sequence, DNA holds an additional layer of information through chemical modifications, known as epigenetic changes [99]. These changes can alter gene expression and are linked to diseases, including cancer [100].

One extensively studied epigenetic change involves adding a methyl group (-CH₃) to cytosine residues, primarily those in CpG sites within the human genome. This has led to interest in forensic DNA methylation analysis, focusing on estimating a donor's age and identifying tissue types in biological samples [102–105]. It also has broader forensic applications, like distinguishing monozygotic twins [105] and determining smoking status [106].

Differential DNA methylation plays a role in cell differentiation, leading to tissue-specific methylation patterns at CpG sites [100]. This has been used to develop methylation-based assays using various technologies [103,104]. Studies have identified epigenetic markers for identifying tissue types such as blood, semen, saliva, vaginal material, and menstrual blood, though some pose greater challenges [107–114]. Identifying tissue type through DNA analysis allows for linking an STR profile with the corresponding tissue type since both come from the same molecule [79,103].

Predicting an individual's age from a DNA sample is valuable, especially when combined with the prediction of externally visible characteristics (EVCs), some of which change with age [103]. Researchers have identified CpG sites where methylation levels correlate with age and built age-prediction models using technologies like pyrosequencing, SNaPshot chemistry, and EpiTyper [118–120]. While universal age-related markers would be helpful, tissue-specific models achieve the highest accuracy [102,104,121–123], mostly in whole blood [124–128], with some extending to saliva and semen [115,129–132]. MPS-based targeted methylation assays have also emerged, offering high accuracy, typically within ± 3 –4 years [79,103].

19. Forensic DNA Phenotyping

When standard STR profiling falls short in investigations, the need to identify the sample donor becomes critical. Predicting externally visible characteristics (EVCs) from DNA samples is a valuable tool, aiding investigations by narrowing down potential suspects [77]. Forensic DNA phenotyping (FDP) covers EVC prediction, bio-geographic ancestry inference, and age estimation using epigenetic markers [78,79].

FDP techniques stem from research on SNPs linked to traits through genome-wide association studies [80]. These studies pinpoint small SNP sets for PCR multiplex analysis and statistical models, delivering highly accurate human pigmentation trait predictions, primarily for eye, hair, and skin color [77].

Several systems predict human pigmentation traits, including validated assays like IrisPlex [82,83], HIrisPlex [84,85], and HirisPlex-S [86,87]. They analyze 6, 24, and 41 SNPs, respectively, predicting broad eye, hair, and skin color categories. Enhanced models and additional SNPs boost accuracy, often measured by AUC values (0.5 to 1.0) [77].

For example, the latest IrisPlex model predicts brown eye color with 0.95 accuracy, blue with 0.94, and intermediate (e.g., non-blue and non-brown) with 0.74 accuracy, averaging 84%, or 93% for blue and brown categories [85]. Similarly, HIrisPlex predicts hair color with accuracies of 0.92 for red, 0.85 for black, 0.81 for blond, and 0.75 for brown, averaging 73% [85]. Hair predictions can be affected by age-related hair darkening, resulting in lighter hair predictions for some categorized as brown but predicted as blond [84]. HIrisPlex-S predicts skin color for 3 and 5 categories, yielding AUC values between 0.72 and 0.97 [86,87].



Advances in MPS technologies allow the analysis of numerous genetic markers in a single run, even with low DNA input, leading to commercial and custom assays for ancestry and/or EVC prediction [88,89]. VISAGE Consortium researchers combined 41 HRisPlex-S SNPs with 115 ancestry-related SNPs for assays compatible with various MPS platforms [90,91]. VISAGE, an EU-funded program known as VISible Attributes through GENomics Consortium, aims to provide intelligence on appearance, age, and ancestry from DNA in investigations [92,93]. The consortium addresses legal, regulatory, and ethical complexities surrounding EVC prediction from DNA for forensics, often not covered by specific legislation in many countries [92,93]. VISAGE and other researchers continue to advance systems for predicting various EVCs, including eyebrow color, stature, skin features like freckles and tanning, and additional hair-related phenotypes such as head hair shape and age-related hair darkening [94,95,96,97,98].

20. Genetic Genealogy

Since the widely publicized arrest of Joseph DeAngelo in 2018 as a suspect in the Golden State Killer case, genetic genealogy's application in forensics has garnered significant attention [135,136]. While familial searching in forensic DNA databases has effectively identified close relatives (first or second degree) by detecting shared alleles in STR profiles, genetic genealogists can uncover more distant relatives (from third to ninth degree) by identifying stretches of identical-by-descent DNA, indicating shared ancestry [137]. This is made possible by leveraging extensive genetic datasets from individuals who have taken direct-to-consumer (DTC) genetic tests for genealogical research purposes. These tests analyze hundreds of thousands of autosomal SNP variants, and the results are shared on public platforms like GEDmatch (<https://www.gedmatch.com/>), enabling test-takers to identify potential relatives [138,139].

Criminal investigations now use profiles generated from samples to search these online platforms, potentially identifying relatives of the suspect. Subsequent genealogical research may lead to the identification of a suspect whose DNA can then be obtained and compared with crime samples [140]. The size of these public genetic databases is substantial, with one study estimating that 60% of searches could find relatives as close as third cousins or closer, and 15% as second cousins or closer. This suggests that a database covering only 2% of a target population could yield third cousin matches for 99% of the population ([141], see also [142]). Most individuals who have undergone

DTC genetic testing in genealogical databases are US citizens of European descent, increasing the likelihood of finding relative matches in this population [140,141]. However, there is growing interest in other populations, both in the adoption of DTC genetic testing and its utilization by law enforcement agencies. Since DeAngelo's arrest and other notable successes, law enforcement agencies worldwide have recognized the potential of this approach for identifying distant relatives of suspects [138].

This approach has raised concerns regarding data privacy and ethics due to covert law enforcement searches of public databases. Nevertheless, many platforms accessible to law enforcement either provide consumers with the option to opt-out of such searches or explicitly require them to opt in [140,143]. Persistent concerns revolve around data sharing, privacy, the legality of these searches, and the ethics of individuals who haven't undergone genetic testing being scrutinized by investigators because of a relative's DNA [137,144–146]. Additionally, there are no validation studies specifically for forensic genealogical techniques [138,139]. However, these techniques are primarily used to generate investigative leads, often in cold cases, and any leads are always verified using standard STR profiling [140]. With GEDmatch recently acquired by the forensic genomics company Verogen (<https://verogen.com/gedmatch-partners-with-genomics-firm/>) and the launch of a kit designed for genealogical applications (<https://verogen.com/products/forenseq-kintelligencekit/>), it appears that these methods will become more commonplace in investigations.

21. Mitochondrial DNA Analysis

In the past quarter-century, mitochondrial DNA (mtDNA) typing has played a significant role globally in addressing various aspects of human identification, ranging from resolving cases of violent and minor crimes to acts of terrorism, mass disasters, and missing persons' investigations. The advancements in mtDNA typing have been remarkable, transitioning from the analysis of small DNA fragments, which used to take several days, to the rapid sequencing of complete mtDNA genomes within a matter of hours. MtDNA, as a lineage-based genetic marker, offers insights into ancestral heritage and can also provide information related to health and disease predisposition.

While many acknowledge the importance of researchers obtaining information about an unknown suspect's potential ancestral background, there remains a contentious debate regarding the use of these technologies to determine genetic predispositions to specific disorders. Therefore, it is imperative that emerging



mitogenome sequencing technologies are employed judiciously, with a clear understanding of their intended purposes, focusing on their distinct roles and contributions within the realm of forensic human identification.

Certain concerns persist regarding the admissibility of mtDNA analysis in legal proceedings, particularly concerning issues such as heteroplasmy and, more recently, the possibility of biparental inheritance. Addressing these concerns necessitates a comprehensive understanding of the molecular mechanisms governing biparental mtDNA inheritance, the ability to identify situations where this may occur, and the capacity to accurately detect and characterize heteroplasmy. These endeavors are crucial for ensuring the reliability and robustness of mtDNA as a valuable and alternative tool in the field of forensic human identification.

22. The Key Policy Recommendations

22.1 Quality Control and Standardization

Definition

The conduction of any scientific test that may have implications for an individual's liberty, especially in criminal cases, demands the highest level of diligence and precision. DNA typing is no exception to this rule. It encompasses a complex, multi-step process that should only be executed by proficient and rigorously trained experts. This careful approach ensures the acquisition of accurate results and their correct interpretation. When conducted correctly, DNA testing serves as a powerful investigative tool for the law enforcement community, producing results that can withstand rigorous legal scrutiny.

However, past experiences have shown that issues can arise when laboratories deviate from validated protocols or employ inadequately trained personnel. To underscore the significance of maintaining exemplary laboratory practices in obtaining scientifically sound results, two fundamental concepts are often emphasized: quality assurance (QA) and quality control (QC). Quality assurance involves meticulously planned and systematic actions aimed at instilling confidence that a product or service will meet specified quality requirements. Conversely, quality control pertains to the day-to-day operational techniques and activities employed to ensure the fulfillment of quality standards.

In practice, organizations strategically devise QA measures and implement QC activities within their laboratories. The forensic DNA community has long

recognized the paramount importance of delivering high-quality results. Early in the evolution of forensic DNA technology, organizations were established to provide guidance on quality assurance principles and oversee the implementation of quality control measures. These efforts reflect the unwavering commitment to maintaining the integrity and reliability of forensic DNA analysis.

23. The India v/s International Scenario

While the National Accreditation Board for Testing and Calibration Laboratories (NABL) serves as the primary accreditation body for forensic laboratories in India, the realm of DNA testing presents unique challenges that demand comprehensive guidelines and regulations. DNA testing stands as the gold standard analytical technique within the justice delivery system, and as such, it necessitates the implementation of stringent quality assurance standards.

However, it is worth noting that, within the context of Indian forensic laboratories, there is a significant gap when it comes to established quality assurance standards specifically tailored for DNA testing. Unlike some other testing and calibration fields, DNA analysis is distinct in its potential impact on legal cases, human lives, and the broader criminal justice system. As a result, a specialized framework of guidelines and regulations is essential to govern this critical area of forensic science.

Unfortunately, the current landscape in Indian forensic laboratories reveals a deficiency in universally accepted and notified quality assurance standards for DNA testing. Moreover, the absence of universally applicable Standard Operating Procedures (SOPs) compounds the issue. Instead of standardized protocols, there exists a considerable degree of variation in the analysis and reporting SOPs across different state and central forensic laboratories in India.

This lack of standardized guidelines and SOPs poses several challenges. Firstly, it can lead to inconsistencies in the procedures followed for DNA testing, potentially impacting the accuracy and reliability of results. Secondly, the absence of a common framework can hinder effective collaboration and information sharing among forensic laboratories. Furthermore, it can create difficulties in ensuring the admissibility of DNA evidence in court, as standardized procedures and quality assurance measures are critical for establishing the credibility of forensic findings.

If we look at the international scenario for quality assurance standards, a total of 70 documentary standards and guidance documents related to forensic DNA have



been published by various organizations in the past three years (2019–2022) in the United States, UK, Australia, and the European Union. Scientific Working Group in DNA Analysis Methods (SWGDM) is the major organization which.

The Federal Bureau of Investigation (FBI) Laboratory plays a crucial role in advancing the field of forensic biology by providing support and funding to the Scientific Working Group on DNA Analysis Methods (SWGDM). SWGDM serves as a vital forum where experts gather to discuss, exchange, and evaluate various aspects of forensic biology methods, protocols, training, and research.

One of the significant functions of SWGDM is to create comprehensive guidelines on a wide range of topics relevant to forensic biology. The group convenes semi-annually, in January and July, to facilitate these discussions and knowledge-sharing initiatives. Additionally, SWGDM has the important responsibility of offering recommendations to the FBI Director concerning the Quality Assurance Standards (QAS) employed in the assessment of U.S. forensic DNA laboratories participating in the National DNA Index System (NDIS). These laboratories are actively involved in DNA databasing and forensic casework. Notably, new versions of the QAS were introduced and became effective on July 1, 2020.

Throughout the period from 2019 to 2022, SWGDM has produced several valuable work products and resources (as detailed in Table 2). These include audit documents and guidance related to QAS, updates to guidelines for mitochondrial DNA analysis and short tandem repeat (STR) interpretation with a focus on next-generation sequencing (NGS) technologies, guidance on training, as well as guidelines for interpreting Y-chromosome data. Furthermore, SWGDM has contributed to enhancing the capabilities of forensic laboratories in the United States by updating the Y-chromosome Haplotype Reference Database (YHRD) specifically tailored for U.S. laboratories. Additionally, SWGDM has released insightful reports on investigative genetic genealogy and the utilization of Y-screening for evidence kits related to sexual assault cases. It is important to note that these valuable documents and resources are readily accessible online, fostering transparency and knowledge dissemination within the forensic biology community.

This collaborative and information-sharing effort led by SWGDM underscores the commitment of the FBI Laboratory and the broader forensic science community to continually improve and uphold the highest standards in forensic biology, thereby ensuring the integrity and reliability of DNA analysis in the

field of criminal justice.

Most of the world either follows the QAS published by SWGDAM or make their own based on the same. India should review those standard.

24. Recommendation

To address these challenges and elevate the quality and reliability of DNA testing in Indian forensic laboratories, it is imperative to establish a dedicated Council of Forensic Science should be established. This council then shall develop and implement stringent, uniform, and widely accepted quality assurance standards and SOPs tailored specifically to DNA analysis. These standards should encompass every facet of DNA testing, from sample collection and handling to laboratory analysis and result interpretation. Establishing such a framework would not only enhance the credibility of forensic DNA analysis but also contribute to the fair and just administration of justice in India.

Furthermore, following measures/practices should be implemented to overhaul the current quality assurance state of forensic laboratories in India.

1. Given the existing disparities in adherence to established scientific and quality assurance standards, we propose conducting a comprehensive scientific audit of the operational DNA profiling divisions within all Forensic Science Laboratories (FSLs).
2. This crucial audit should be meticulously planned and executed through collaborative efforts involving the National Forensic Sciences University (NFSU) and the proposed Council of Forensic Science including independent scientific experts specializing in DNA profiling methodologies.

24.1 Research and Development Funding

Regrettably, the state of research and development (R&D) funding within forensic laboratories, including Central Forensic Science Laboratories (CFSLs), in India remains a glaring concern. None of these laboratories, renowned for their pivotal role in forensic investigations, have allocated any financial resources to support research and development initiatives. This deficiency can be attributed to various factors, notably the overwhelming backlog of pending cases and the perennial shortage of staff, which collectively hinder their capacity to engage in research activities.

This predicament becomes especially disconcerting when considering the initial vision for CFSLs as bastions of innovation and research in the realm of forensic

science. In the year 1998, three CFSLs located in Hyderabad, Chandigarh, and Kolkata were bestowed with the prestigious designation of being ‘Centres of Excellence.’ Each of these centers was dedicated to distinct facets of forensic science, encompassing Forensic Chemical Sciences, Forensic Physical Sciences, and Forensic Biological Sciences, respectively. The primary mandate of these specialized laboratories was to spearhead pioneering research initiatives. To support this ambitious objective, states were explicitly urged not to divert “routine” cases to CFSLs, instead opting to have them examined within their respective State Forensic Science Laboratories (SFSLs).

However, the landscape of this compartmentalized research mandate underwent a significant transformation following the establishment of three additional CFSLs in Bhopal, Pune, and Guwahati. In this context, the previous distinctions delineating research responsibilities were dismantled, and a more holistic focus on research and development was advocated for all CFSLs under the Directorate of Forensic Science Services (DFSS).

Despite these strategic shifts and the commendable vision of positioning CFSLs as incubators for pioneering research endeavors, the critical missing piece remains the allocation of funds to facilitate meaningful R&D activities. As a result, the laudable potential of CFSLs to contribute to advancements in forensic science through research remains largely untapped and unrealized.

Now, it’s important to consider the ‘Make in India’ mandate of the Government of India in this context. The ‘Make in India’ initiative is a visionary program aimed at transforming India into a global manufacturing hub by promoting indigenous production and innovation across various sectors. Within the purview of forensic science, this mandate takes on particular significance. Allocating adequate funds for research and development in forensic laboratories aligns seamlessly with the ‘Make in India’ vision. By fostering innovation and knowledge creation within the realm of forensic science, these laboratories can not only enhance their own capabilities but also contribute to the development and production of cutting-edge forensic technologies and methodologies on Indian soil.

In essence, addressing the funding deficit in forensic laboratories for R&D activities not only promotes scientific innovation but also aligns with the broader national agenda of self-reliance and indigenous manufacturing, as envisioned by the ‘Make in India’ initiative. It is imperative that steps are taken to mobilize financial resources explicitly dedicated to research and development within these laboratories to unlock their full potential in advancing the field of forensic

science while contributing to the nation's self-sufficiency goals.

24.2 Data Management and Sharing

A forensic DNA database plays a pivotal role in enhancing the efficiency of crime investigations by connecting DNA profiles obtained from biological evidence found at crime scenes to each other and potentially identifying the donors or their relatives. This approach has demonstrated its effectiveness in the field of forensic science over the last two decades, aiding investigations globally.

However, it's noteworthy that despite the demonstrated success of forensic DNA databases in numerous countries, including India, the implementation of such databases remains a pending endeavour. Many nations, India included, have yet to establish their own DNA databases, missing out on the advantages and capabilities these databases offer for criminal investigations. It is imperative for every nation to establish a forensic DNA database to:

- Improve the likelihood of resolving criminal cases.
- Increase the rate of successfully solved crimes.
- Accelerate the pace at which crimes are resolved.
- Free up law enforcement resources for other essential tasks.
- Enable the linkage of unsolved criminal cases.
- Enhance the capacity to identify cases involving false identities.

Based on the recent guidelines for DNA Database Management Review and Recommendations published by ENFSI, the following major recommendations are proposed for India to initiate:

1. **Establishment of a Forensic DNA Database:** India should create a forensic DNA database and enact specific legislation to govern its establishment and management.
2. **Selection of Suitable STR Loci:** The Council of Forensic Science, in consultation with relevant stakeholders, should identify the most appropriate STR loci and determine the minimum number of STR loci required for DNA profiles.
3. **Laboratory Accreditation:** Laboratories responsible for generating DNA profiles for the database should, at a minimum, obtain ISO-17025 (or equivalent national) accreditation and participate in proficiency tests to ensure the accuracy of their work.

4. **Regular Communication:** The custodian of the DNA database should maintain regular communication with DNA profile suppliers, sharing information about legal and technical developments, changes in inclusion and matching rules, and other pertinent matters.
5. **Analysis of Mixed Profiles:** Guidelines outlined in the ISFG working group document on the analysis of mixed profiles should be followed. Validated software tools may also be utilized for this purpose.
6. **Database Contents:** Databases may include only autosomal STR profiles. For databases containing non-autosomal STR profiles or mitochondrial DNA sequences, specific operating procedures must be established to prevent unintended familial searches and ensure clear differentiation from the rCRS when comparing mtDNA results.
7. **Profile Deletion:** Policies and procedures should be in place to facilitate the removal of DNA profiles that are no longer relevant, as determined by the authorizing agent.
8. **Error Prevention:** Human errors related to data entry should be minimized through automation of the allele calling and DNA database import processes. When manual entry is necessary, measures such as double-blind data entry should be implemented to detect typing errors.
9. **Monitoring and Communication:** Given the public, political, and media scrutiny that national DNA databases attract, DNA database managers should establish tools for monitoring the database's effectiveness and communicate this objective information publicly.
10. **Adventitious Matches:** Database managers should be aware of the potential for adventitious matches and should be capable of calculating expected match numbers, considering factors such as database size, search volume, mixed profiles, random match probability, and the presence of family members.
11. **Informative Match Reports:** Reports detailing a DNA database match between a crime scene-related DNA profile and an individual should be informative. They may include an assessment of the evidential value of the match (RMP/LR), a warning about the possibility of adventitious matches (as mentioned in recommendation 10), and an acknowledgment that the match should be considered alongside other evidence.
12. **International Collaboration:** Well-defined policies should be in place to guide the sharing of DNA profiles in the context of international collaborative investigations.

These recommendations aim to establish a robust and ethical framework for the development and management of a forensic DNA database in India, aligning it with international best practices and standards.

25. Ethical and Legal Considerations

25.1 Privacy Protections

With the increased use of DNA databases, there is a growing need for robust privacy safeguards to prevent users' DNA data from being exploited. DNA databases are becoming more prevalent with companies offering DNA testing services, governments collecting DNA data for law enforcement purposes and research institutions storing DNA data for medical research. Though not in India currently but once the Act permits implementation of DNA database, perceived scenario might be experienced in Indian Labs as well. However, these databases can be vulnerable to security breaches and personal information. This highlights the importance of having strong privacy safeguards that can protect user data and prevent unauthorized access. Here are some of the main justifications for why certain protections, such as informed consent, restrictions on data retention, and defence against illegal access, are essential:

25.2 Informed consent

Informed consent is a crucial process that ensures participants are aware of the risks and benefits of participating in a medical procedure research study before deciding whether or not to participate. It is especially important in the context of DNA research, as it is sensitive and may be used in discriminatory ways. To ensure proper information about the collection, use, and sharing of genetic data, robust privacy measures are required (Wan et al., 2022).

Individuals' consent should be obtained prior to their involvement in a study or the sharing of their genetic data with third parties, emphasizing the goal, extent of data usage, expected outcomes, and predicted risks and advantages of data release. This transparency fosters trust between individuals and data custodians (Clayton et al., 2018). Informed consent can help reduce privacy violations, stigmatization, and loss of control over personal data. It also enables people to decide whether or not to participate, lowering the possibility of coercion or exploitation (Taub et al., 2004).

However, there are challenges in obtaining informed consent, such as educating the general public about the implications of giving samples, addressing potential

misuse of data, and addressing power disparities. Linguistic barriers, cultural taboos, and lack of diversity and representation in research hinder inclusive privacy rules that consider the demands of all stakeholders. To ensure everyone's rights and privacy are safeguarded, these obstacles must be considered when implementing privacy measures in DNA databases.

25.3 Limitations on Data retention

Data retention restrictions are essential measures to protect people's privacy in DNA databases. These limits limit the storage of DNA or genetic information, ensuring that individuals are protected against potential privacy violations and exploitation. DNA databases can be useful for forensic analysis and scientific research, but their value must be weighed against the need to protect the confidentiality and privacy of the people whose genetic information is being saved. Enforcing data retention is a crucial step in encouraging ethical DNA use and respecting people's right to privacy.

DNA database data breaches can have significant repercussions for both individuals and society, as high-value data may be lost, leading to theft, insurance fraud, and other malicious uses. Additionally, if the breach is significant enough, it can jeopardize the database's integrity, jeopardizing possible R&D initiatives (Malakar et al., 2023). Strong privacy protections are necessary to prevent illegal access and ensure the security of information due to the growing importance of DNA databases in industries like forensics, healthcare, and ancestry testing.

As DNA databases are used more frequently, there is a greater chance of misuse. Criminals have been known to exploit DNA databases to locate potential victims or threaten people with the disclosure of private genetic data. Governments and other organizations have also been charged with exploiting DNA data for surveillance to discriminate against people based solely on their genetic makeup. To prevent data retention, three limits must be implemented: time limit, purpose limit, and user limit. Time limits refer to the precise times DNA samples and related data are processed and kept, while purpose limits ensure that data is only used for the specific purpose for which it was collected and with necessary consent. User limitations are also crucial for preserving individual privacy and shielding people from the misuse of their personal data. Companies that gather DNA information must be upfront about their intended purpose and have a clear knowledge of the intended purpose. User limitations restrict access to those with a genuine need for the data while protecting sensitive information.

25.4 Ensuring protection against unauthorised access

Ensuring protection against unauthorised access to DNA databases is crucial for maintaining trust and preventing misuse, discrimination, and identity theft. DNA databases should have robust security protocols, including strong passwords, encryption, and control measures. Biometric identification, such as fingerprints or recognition, can enhance security. Regular audits and monitoring ensure legitimate and authorized access.

In today's digital age, protecting sensitive data is essential for safeguarding individuals' rights and preventing misuse. Human error is a significant issue in online DNA, and measures should be taken to minimize the risk of human error. Prioritizing patient privacy safety and data accuracy is essential for ensuring the security and privacy of DNA databases. Various strategies can be employed to safeguard DNA data privacy, including encryption, access controls, monitoring and auditing, oversight, and enforcement, and maintaining public trust. Encryption methods must be robust and updated regularly to protect against emerging threats. Access controls, such as multi-factor authentication, password protection, and user permissions, are essential for preventing breaches and unauthorized use of sensitive DNA data. Monitoring and auditing are crucial components of ensuring user privacy.

25.5 Oversight and enforcement

Oversight and enforcement are essential components of establishing robust privacy safeguards in DNA databases. Ensuring oversight compliance with established policies and regulations, creating accountability mechanisms, and updating enforcement measures are essential. Addressing non-compliance is crucial, as non-compliance can lead to compromised data security, breach of privacy, and liabilities. Organizations must establish effective policies and enforce strict penalties for violations, fines, legal action, and public disclosure.

Maintaining public trust is essential for DNA databases to prioritize privacy safeguards. If the public perceives the system as unsafe or unreliable, it could lead to a lack of participation in medical, investigation, and identifying missing persons. Implementing security measures and respectful policies can ensure that stakeholders remain confident in the system and comfortable contributing their DNA information for research purposes.



25.6 Familial DNA Searching

Genetic familial testing may be defined as a deliberate search of a DNA database using specialized software (separate from CODIS) to detect and statistically rank a list of potential candidates in the DNA database who may be close biological relatives (e.g., parent, child, sibling) to the unknown individual contributing the evidence DNA profile, combined with lineage testing to help confirm or refute biological relatedness (Debus-Sherrill & Field, 2017).

In crime investigations, “familial searching” is defined as the intentional search of an offender’s DNA database for inexact matches between DNA evidence profiles and offender and arrestee DNA profiles. Upon the identification of one or more partial match profiles, law enforcement may investigate purported family members of the partial matches as suspects. Such familial searching has identified and convicted suspects, allowed investigators to reopen cold cases, and exonerated wrongfully convicted individuals.

Familial searching has immense potential to help law enforcement develop leads in investigations that would otherwise go unsolved. However, this novel approach presents both technical and logistical challenges for law enforcement, raising distinct ethical, social, and legal concerns (Kim et al., 2011). As policies governing familial searching develop, policymakers, law enforcement agencies, and the public may consider options for improving the effectiveness and reliability of familial searches, the potential effects on society and families, the associated Fourth Amendment implications, and the costs and benefits to law enforcement.

A familial search is a low-stringency search aimed at identifying a relative of the perpetrator, often resulting in parent-offspring relationships. This type of search is more likely to result in close biological relatives, but partial matches may also include random unrelated individuals profiled in CODIS whose DNA profiles are similar to the evidence sample profile. The resulting suspect pool can contain from a few to hundreds of suspects, depending on the search parameters used. To maximize the efficiency of investigations and limit unwarranted scrutiny on innocent individuals, additional analysis is necessary to verify the relatedness between the evidence profile and the partially matched offender. The DNA Identification Act of 1994 does not explicitly authorize familial searches at the federal level, and searches of the National DNA Index System (NDIS) are not currently conducted. The latest edition of the CODIS database (CODIS 7.0) will not include familial searching capabilities. However, the Scientific

Working Group on DNA Analysis Methods (SWGDM) proposed protocols for pursuing incidentally found partial matches and made recommendations on further analysis to confirm relatedness.

Familial searching approaches can have both positive and negative effects on individuals, families, and society. Proponents argue that the potential to improve public safety and ensure justice outweighs any costs to individual and family privacy. (Kim et al., 2011; Noble AA., 2006; Sonia M. Suter*, 2010). The United Kingdom successfully used familial searching to obtain convictions in 19 cases between 2003 and 2010. To address ethical concerns, the UK established the National DNA Database Ethics Group, which monitors all ethical and human rights concerns related to searches. California formed a Familial Search Committee (FSC) to review familial search requests and provide legal and ethical checkpoints at major steps in the investigation. Family members may learn information about relatives that was previously unknown to them, potentially leading to domestic violence or estrangement. To mitigate this risk, policies may require verification of familial relationships through public records as a prerequisite for questioning suspects.

Abuse of power is another concern, as familial searching opens the investigation of potentially innocent individuals based on their genetic material. People argue that this leads to increased genetic surveillance and abuse of power by law enforcement officers and agencies. To limit the abuse of power, California, Texas, and Virginia authorize familial searches only after all other investigative options have been exhausted.

In implementing a familial search policy, there are six policy options (Kim et al., 2011), which aim to maximize system efficiency, limit the burden on laboratories and law enforcement, address impacts on society and families, and balance ethical implications with law enforcement officials' responsibilities and public safety.

- i.) The centre could be granted authorization to develop software to search CODIS for biological relatives, ensuring consistency across jurisdictions. This would require standard tools to manage candidate suspect pools and minimize the burden on law enforcement officials and privacy intrusion on families.
- ii.) National policy could be established to type YSTR markers for all prospective CODIS profiles, improving efficiency by removing the need for retesting. Individual states could develop policies for retesting stored DNA samples

for YSTR markers based on their available resources and familial searching needs.

- iii.) A national advisory consortium could be established to guide the development of statistical tools for familial searching, ensuring consistency across jurisdictions. This would involve expert advice on relationship testing, statistics, and population genetics.
- iv.) A national advisory consortium could be established to review cases and serve as an ethics advisory function in policy implementation. This would guide the ethical boundaries and privacy concerns of familial searching, as well as recommendations regarding police investigation approaches.
- v.) States could determine for which crimes familial searching is appropriate, weighing the needs to prevent crime, protect the public interest, and protect individual privacy rights. This could include searches of innocent individuals with diminished privacy expectations or broaden the scope of familial searches to include categories of offenders.
- vi.) Familial searching policies should consider population impact and minimize personal intrusion on relatives, enhancing understanding of societal impact as procedures develop.

25.7 Regulation of Emerging Technologies

A regulatory framework for emerging DNA analysis technologies is essential to ensure responsible and ethical use of these cutting-edge tools. It should provide clear guidelines for data use, security measures, and accountability measures for misuse or mishandling of DNA. Emerging DNA analysis technologies, such as CRISPR-Cas9 gene editing, and DNA analysis techniques, such as polymerase chain reaction (PCR), DNA sequencing, and microarray analysis, have advanced significantly, allowing for rapid and inexpensive genome sequencing. However, these technologies raise ethical and social concerns, such as privacy, genetic discrimination, and informed consent. Ethical considerations are crucial in designing a regulatory framework, as they provide access to personal genetic information and must ensure informed consent, and privacy rights, and avoid discrimination based on genetic traits. Technical considerations for regulating DNA technologies include accuracy, reliability, well-defined storage and management, transparency, and accessibility. Integrating these technologies with existing regulatory frameworks ensures they adhere to ethical and legal standards. A multidisciplinary committee of experts in genetics, law, bioethics, and industry should oversee the development and application of DNA analysis

technologies. This committee should set guidelines, conduct risk assessments, and ensure proper protocols are in place to protect genomic data.

A regulatory framework is essential for responsible use and preventing unintended consequences of emerging DNA analysis technologies, as they present significant ethical and privacy concerns. It is crucial to strike a balance between facilitating innovation and protecting public safety and privacy. Collaboration between stakeholders, including the government, players, and research institutions, is essential to ensure the full realization of the benefits of DNA analysis technologies while avoiding unintended consequences.

India needs to focus on improving the current DNA collection and analysis system, as well as addressing the challenges faced by public crime labs, researchers, and the criminal justice system. A National Forensic Science Commission should be created to assess the needs of the forensic science community and raise public awareness of forensic technology's use in crime solving (*Advancing-Justice-through-Dna-Technology-Using-Dna-Solve-Crimes*, n.d.). The Commission will study advances in forensic sciences, make recommendations, and serve as an ongoing forum for discussing initiatives and policy.

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26. Capacity Building and Training

26.1 Infrastructural Development

Recommend investment in state-of-the-art laboratory infrastructure, including equipment, facilities, and IT systems. Upgrading infrastructure will enable laboratories to handle advanced DNA analysis techniques efficiently.

26.2 Workforce Development

Propose initiatives for training forensic personnel in the latest DNA analysis techniques, ensuring a skilled workforce capable of handling advanced technologies.

26.3 Public Awareness Programs

Suggest public education campaigns to raise awareness about the benefits, limitations, and implications of DNA forensics, fostering a better-informed society.

27. International Cooperation

27.1 Global Standards

DNA technology plays a pivotal role in numerous laboratories engaged in the field of criminal/Forensic investigation on an international level. The success of these laboratories heavily relies on the standards procedures used for proper collection, documentation, storage and analysis methods for evidence collected from crime-scène and reference samples. It is essential to ensure that DNA analysis is performed in a way that optimizes the integrity, quality, reliability, and global acceptance of the obtained results. In an increasingly interconnected world, advancements in genetic research and technology have led to a need

for standardized universally accepted methods. However, DNA analysis cannot reach its maximum potential without international standards for DNA analysis, data sharing, and collaboration.

27.2 Need for International Standards

International DNA analysis standards have to be adopted for a number of reasons. Molecular biology employs a number of distinct techniques and technologies for DNA analysis. Along with that, the data generated by DNA based studies is often shared between different countries and organizations. The data generated can be used for a variety of purposes, including criminal justice, immigration, and public health. Without globally accepted standards, the analysis results raise concerns regarding accuracy, reliability, data sharing, and how to utilize this data in a secure and ethical way. The present set of standards should explore the necessary criteria for the analysis of DNA, encompassing the processes of sampling, extraction, amplification, and typing of DNA.

There are a number of existing international standards for DNA analysis. International scientific organizations such as the International Society for Forensic Genetics (ISFG) and the International Union of Biological Sciences (IUBS) have played a crucial role in convening experts, sharing best practices, and fostering consensus on DNA analysis standards. Such organizations serve as a forum for scholars and professionals to engage in the sharing of knowledge and actively contribute to the development of internationally recognized guidelines.

In light of the significance of precise DNA analysis within the context of criminal investigations, numerous governments have implemented national DNA databases and established regulatory entities to supervise DNA-related endeavors. These organizations engage in worldwide collaboration to harmonize practices and guarantee the interoperability of DNA profiles across different countries. The facilitation of standard harmonization is further enhanced by the formation of bilateral agreements and active involvement in global forums. The need for standardized DNA analysis transcends national boundaries, leading to the creation of international agreements and treaties. Such agreements allow participating countries to compare DNA profiles for various purposes, including law enforcement and border control.

27.3 Challenges to Establishing International Standards

There are a number of challenges to establishing international standards for DNA analysis. As DNA based study involves sensitive personal information,

ethical considerations are at paramount. The challenges of maintaining uniform standard procedures are inherent in the cultural and legal variations observed throughout different regions globally. The acceptability of certain behaviors or practices can vary across different countries. International standards also address privacy concerns, consent requirements, and the responsible use of genetic data. Organizations like the UNESCO's International Bioethics Committee contribute to the development of guidelines that strike a balance between scientific progress and individual rights.

In addition, it is recommended to establish a correlation between the rapid pace of advancement in technology. As new DNA technologies are developed, it can be difficult to keep up with the latest standards and implementation of these standards to collaborative institutes.

27.4 Joint Investigative Efforts

DNA forensics has transformed the landscape of criminal investigations, particularly in cross-border cases. Collaborative efforts between countries are essential to harness its full potential. By sharing resources, knowledge, and expertise, nations can transcend jurisdictional boundaries and tackle cross-border crimes effectively, ensuring that criminals cannot exploit geographical differences to evade justice. The future of international law enforcement lies in the continued enhancement of collaborative approaches, with DNA forensics serving as a cornerstone in the pursuit of global security and justice.

Conclusion

Key policy recommendations outlined in the chapter

1. First and foremost, thorough training is needed for all the law enforcement officials involved in the investigation of the crime scene cases, as well as the collection, preservation of biological evidences, DNA profiling, and uploading of DNA data once generated at appropriate platform. Since police officers are now ill-equipped to take samples and secure them from being leaked or destroyed, frequency of cases with evidence manipulation increases. All police personnel must receive training on how to gather and upload pertinent data into databases so that it can be used for profiling and subsequent forensic analysis as and when required.
2. Another recommendation that may be considered is that collection, preservation and processing of samples must be done by law enforcement officers who can work independently of the police system, to dispel the fear

of collusion between investigative bodies and evidence collectors

3. Extensive Training has to be provided to all the law enforcement officers including judiciary and sensitize them about the importance of forensic evidence,
4. With most of the forensic experts working in the FSLs are overburdened, possibility of undertaking research and development in advanced technological development is hampered. Recruiting man power on larger scale will reduce pendency of cases, and allow forensic experts to indulge in more R & D activities that will help in improving scientific certainty of forensic evidences.
5. While also reiterating the fact that arbitrary law, non-scientific practices, lack of skilled man power and lack of scientific temper can lead to a greater mishap in the system and affect rights of individuals.

While there is a huge paucity of forensic science laboratories in India, the in-flow of biological samples always exceeds the number of cases required to be disposed off after analysis. Ultimately this results in huge backlog of cases, rendering some of the biological sample unanalyzed due to extensive degradation, and also affecting criminal justice system.

DNA forensic laboratories requires massive make over in terms of infrastructure development, advanced instrumentation facility and acceptance of international quality standards. These will help in robust work flow in generating DNA profiles, interpretation of data in accurate manner, while also adhering to validation criteria, analytical procedures, calibration of equipment and subjecting DNA profiles and staff towards performance audits, while ensuring safety protocols.

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Chapter 14

Unveiling Financial Deception: Power of Forensic Accounting and Auditing

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Abstract

Title: “Unveiling Financial Deception: The Power of Forensic Accounting and Auditing”

Fraud has emerged as a pervasive threat to the financial integrity of organizations across industries, resulting in significant financial losses and reputational damage. In response to this growing challenge, forensic accounting has risen in significance as a potent instrument for uncovering and preventing fraudulent activities.

Forensic accounting is a specialized domain within accounting that combines financial expertise with investigative capabilities to identify, analyze, and deter fraudulent activities. It encompasses a wide range of techniques, including financial statement analysis, data mining, forensic data analytics and investigative interviews. This multidisciplinary approach equips forensic accountants to possess the expertise and tools required to detect fraudulent schemes and gather evidence for legal proceedings. This document explores the essential significance of forensic accounting in the realm of fraud investigation. Policy recommendations advocate for dedicated “Financial Fraud Investigation Facilities” in India, while privacy protections, capacity building and global standards are emphasized. In conclusion, a united, technology-driven strategy is urged to effectively combat financial fraud and safeguard the integrity of financial systems.

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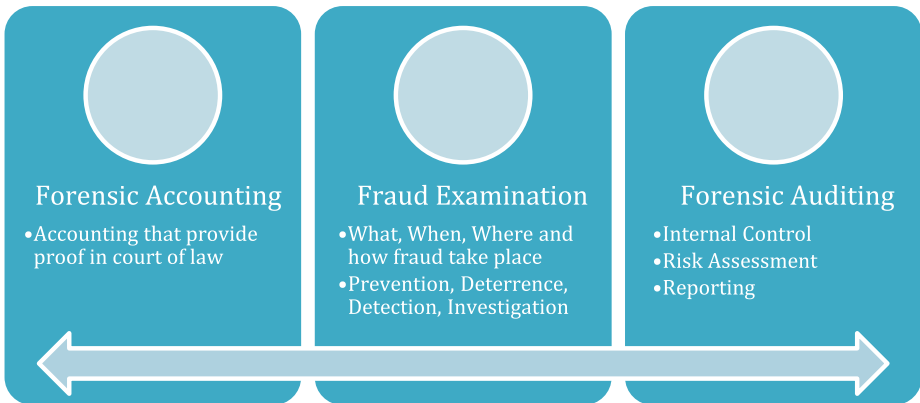
Introduction

Forensic accounting is specialized disciplines within the broader field of accounting that are dedicated to uncovering financial irregularities and fraudulent activities. These fields merge using principles of accounting, forensic methods, investigative techniques, and legal procedures to thoroughly scrutinize financial records, transactions, and documents. Their primary purpose is to identify, document and prevent financial fraud while providing reliable evidence that can be used in legal proceedings.

Forensic accounting entails using accounting expertise to scrutinize financial data and transactions, aiming to uncover indicators of fraud, embezzlement, asset misappropriation, or any other financial misconduct. Forensic accountants are often called upon to investigate complex financial schemes, track the flow of illicit funds and quantify financial damages in legal cases.

On the other hand, forensic auditing focuses on applying auditing techniques to scrutinize financial records and systems for fraud-related issues. This includes assessing internal controls, verifying the accuracy of financial statements and examining financial operations to identify vulnerabilities that might be exploited by fraudsters.

Intersection between Forensic Accounting, Forensic Auditing and Fraud Investigation:



The utilization of forensic accounting and auditing is crucial in conducting financial fraud investigations. These professionals play a pivotal role in not only uncovering fraudulent activities but also in preserving evidence, quantifying financial losses and providing expert testimony in court. They are instrumental

in holding wrongdoers accountable for their actions, recovering stolen assets and helping organizations strengthen their implementing internal controls to mitigate the risk of future fraud incidents.

In a world where financial crimes are becoming increasingly sophisticated and widespread, the expertise of forensic accountants is indispensable for safeguarding the integrity of financial systems and ensuring trust in both corporate and public sectors. Their meticulous analysis and investigative skills are essential for combating financial fraud and upholding the principles of transparency and accountability in the financial world.

The rise of financial fraud/white collar crime has become a significant issue, impacting economies and people on a large scale. These fraudulent activities encompass a wide spectrum, including Financial Scams, Occupational Frauds, Money Laundering among others. Despite efforts to combat these issues, India continues to struggle with a substantial number of reported financial fraud cases.

Industry wise types of frauds:



The provided data illustrates the extent of financial fraud cases and their consequential economic impact on the financial health of the nation.

- Whether it is the Jain Hawala Scam of 1991, the 2G Spectrum Scam worth 1.76 lakh crores, the Coal Allocation Scam amounting to 1.86 lakh crores, the Commonwealth Games Scam of 70,000 crores, the Satyam Scam totaling 9,000 crores or the PMC Bank Scam of 2019 amounting to 4,500 crores, these three decades of scandals have severely impacted the Indian economy.
- According to the Report to the Nations, by Association of Certified Fraud Examiners (ACFE) USA, world losses approximately 4.70 lakh crores

annually due to occupational frauds and India has the largest number of occupational fraud cases, such as Corruption, Fake Billing, Financial Statement Fraud and Expense Reimbursement, in Southern Asia followed by Pakistan, Afghanistan, Bangladesh, Nepal and Sri Lanka.

- Numbers of bank fraud cases increase in three fold during the span of last fifteen years. In financial year 2022-23, Reserve Bank of India (RBI) reported a total number of more than 13,000 bank fraud cases across India involving an appx. amount of Rs. 30,000 crores. India lost at least Rs. 100 crores every day to bank frauds or scams over the past seven years, according to RBI data. Between April 1, 2015 and December 31, 2022 banking fraud worth Rs. 2.50 lakh crores were detected across states.
- Between 2020 to May 2023, GST department reported a GST tax credit and fake refund frauds of total Rs 2.68 lakh crores in appx. 43,000 cases.

The detrimental effects of financial fraud on the financial health of a country are far-reaching and multifaceted. These illicit activities erode the integrity of the financial system, undermine trust in institutions and divert resources away from legitimate economic activities. Addressing and preventing such illicit activities are crucial for maintaining a robust and healthy financial environment.

Legal Landscape of Financial Fraud Investigation:

The legal landscape is a complex and multifaceted one, shaped by a combination of national and international laws, regulations and standards. In many jurisdictions, various agencies including law enforcement, regulatory bodies and private sector entities, collaborate to combat financial fraud. The legal landscape also involves key statutes such as the Sarbanes-Oxley Act, the Dodd-Frank Act, Prevention of Money Laundering Act, Benami Transactions Act etc. which set stringent requirements for corporate governance, financial reporting and the prevention of financial crimes. This complicated legal environment signifies the importance of skilled professionals who understand both the financial complexities and the legal complexities of fraud investigation to ensure that justice is served and financial integrity is sustained.

Financial fraud cases often span multiple jurisdictions, complicating the determination of lead investigative authorities and causing delays. Effective collaboration among agencies with different priorities and procedures can be hindered, leading to inefficiencies. Additionally, many agencies face resource shortages, lack specialized expertise and grapple with privacy concerns when sharing sensitive information. Cross-border cases demand international

cooperation, further complicated by different legal systems.

Addressing these challenges requires improved coordination, increased resources, enhanced expertise, efficient information sharing mechanisms and updated regulations to adapt to evolving financial fraud schemes and technologies.

In India, law enforcement agencies like CBI, ED, DRI, SFIO, and others play a pivotal role in preventing financial crimes. But these agencies operate at different levels of government, from the central level down to the state & local levels and the issues of jurisdiction, absence of seamless coordination among agencies leads to delayed information sharing, duplication of efforts and incomplete understanding of the larger picture. This disjointed approach allows fraudsters to exploit gaps in the system, escape scrutiny and continue their illicit activities. Consequently, the ability to trace and recover misappropriated funds, hold culprits accountable and prevent future financial frauds is compromised.

To enhance the success of financial fraud investigations, there is need for improved collaboration, advanced technology, data sharing mechanisms, trained manpower, a holistic approach and a common platform that provide advanced forensic and technical strengths to various enforcement agencies to combat these sophisticated crimes effectively.

Key Technological Advancements:

Forensic accountants play a crucial role in legal proceedings, investigations and disputes involving financial matters. Key components of forensic accounting include, Investigative Analysis, Fraud Detection & Prevention, Litigation Support, Quantification of Losses, Asset Tracing & Recovery, Due Diligence & Fraud Prevention and Deep Data Analytics. Technology play pivotal role in the field of fraud investigation, offering an advance forensic tools and techniques to combat increasingly sophisticated fraudulent activities.

Subsequent paragraph, briefly explore the most recent development within the purview of forensic investigation pertaining to financial fraud.

- **Big Data Analytics:** Big data analytics is instrumental in financial fraud investigations as it enables the efficient analysis of vast volumes of data to detect fraudulent activities. By processing and examining numerous financial transactions, patterns, and anomalies, investigators can identify irregularities and potential fraud schemes more effectively and immediately. Big data analytics also facilitates real-time monitoring, allowing investigators to detect

and respond to fraud in a timely manner.

- **Predictive Modeling:** Predictive modeling or analysis plays a crucial role in financial fraud investigation by leveraging historical data to anticipate and identify potential fraudulent activities; a Red Flag. By analyzing patterns, trends, and anomalies within large datasets, predictive models can pinpoint suspicious transactions or behaviors that might indicate fraud. These models use statistical algorithms and machine learning techniques to continuously learn and adapt, improving their accuracy over time.
- **Artificial Intelligence & Machine Learning:** AI/ML is a powerful tool in financial fraud investigation that uses algorithms and historical data to make predictions about potential fraudulent activities. In financial fraud investigation, machine learning models can automatically flag suspicious activities, transactions, or accounts in real-time. These models continuously learn and adapt, improving their accuracy over time and helping investigators stay ahead of fraudsters who are constantly evolving their tactics. AI-based systems can also automate routine fraud detection tasks, reducing manual effort and human error.
- **Cryptocurrency Forensics:** The rise of cryptocurrencies has created new challenges for forensic accountants. Cryptocurrencies are often used in illegal activities and their decentralized nature makes them difficult to trace. However, forensic accountants use new techniques to track and recover cryptocurrencies that have been used in fraud or other crimes.
- **Blockchain Technology:** Blockchain technology has emerged as a valuable asset in financial fraud investigation due to its transparent and immutable ledger system. It is employed to securely record and store financial transactions, making it challenging for fraudsters to manipulate or alter records. Investigators can trace the movement of assets and transactions through block-chain, providing a clear audit trail. Moreover, smart contracts, which are self-executing agreements on the block-chain, can automate certain fraud detection and prevention measures. By leveraging block-chain, investigators can enhance transparency, reduce the risk of fraud and improve the efficiency of financial fraud investigations.
- **Preventive Forensic Accounting:** In addition to investigating fraud, forensic accountants are also increasingly being called upon to help prevent fraud from happening in the first place. This is also known as Red Flag Analysis/ Preventive Forensic Accounting. Accountants use their skills to identify and mitigate risks of fraud and to develop controls to prevent fraud from occurring.



- **Regulatory Compliance:** Forensic accountants will need to be familiar with the latest regulations governing financial reporting and auditing. This will help them to ensure that their work complies with these regulations.
- **Communication and Reporting Skills:** Forensic accountants will need to be able to communicate their findings to a variety of audiences, including legal professionals, business executives and the public. They will need to be able to explain complex technical concepts in a clear and concise manner.

Forensic accounting tools and advanced data analysis technology offer a range of crucial benefits in the domain of fraud investigation. These tools efficiently

- **Analyze vast volumes** of financial data, revealing patterns and irregularities that **signal potential fraud**.
- Their capability to uncover complex fraud schemes is invaluable, **unveiling hidden connections** and **layered transactions** that might evade traditional methods.
- **Real-time monitoring** prevents ongoing fraud, while **predictive analytics** foresee risks.
- **Data visualization** simplifies understanding of intricate financial activities, aiding investigators in recognizing anomalies.
- By **reducing human error**, these tools enhance accuracy in fraud detection.
- It also documents evidence accurately, **ensuring integrity** during legal proceedings.

In a rapidly evolving landscape of conventional fraud and digital fraud, technological innovation is not just a necessity; it's a force multiplier that empowers investigators to stay ahead of the curve and safeguard businesses and individuals from financial losses and reputational damage. As the world becomes increasingly complex and interconnected, the need for forensic accountants with specialized skills will continue to grow.

Policy Recommendations:

To effectively combat the rising threats of financial fraud in today's complex business landscape, it is recommended that an official policy be put forth to establish a dedicated "Financial Fraud Investigation Facility" in each **State or Region**.

This facility should be equipped with state-of-the-art forensic accounting tools, advanced technology and a team of highly skilled investigators which will



preserve data centrally and will share it with concern legal enforcement agencies within India and internationally after due procedure.

The Financial Fraud Investigation Facility shall have big data storage mechanism which would not only possess the facility of advance data analytics for future fraud prevention but shall also preserve data of previous cases/fraudsters in terms of their personal details, bank details, previous job/business, biometric details, along with the details of loans previously taken from banks and the current status of the loan, ongoing cases against the individual or company, GST paid, claims, taxes paid, current ownership, previous ownership, PAN card details, offshore accounts etc. Example is “CERSAI”. Where we can find out about the loan taken by individuals.

This will create a centralized data sharing mechanism of all financial transactions and fraudsters in a single place and all government based investigative intelligence agencies will be able to coordinate at one place in less time. They will be able to make a centralized family tree of the fraudster and will be able to do “Asset Tracing” in minimal time.

The policy should outline the facility’s objectives, operational framework, resource allocation, collaboration protocols and mechanisms for staying up-to-date of evolving fraud tactics.

The recommended policy of establishing a “**Fraud Investigation Facility**” offers a significant benefit in bridging the communication gap between various legal enforcement agencies. By centralizing fraud investigation efforts, the facility becomes a hub where different agencies can collaborate seamlessly, reduce duplication efforts and leading to quicker responses.

Privacy Protections and Regulations:

To ensure the privacy and security of financial data, a multi-faceted approach needs to be implemented. This approach involves several essential components to safeguard sensitive information effectively.

- **Clear Data Sharing Agreements:** Collaboration among legal enforcement agencies is crucial, but it should be underpinned by clear data sharing agreements. These agreements must outline the scope, purpose, and limitations of data sharing to maintain privacy standards and protect individuals’ confidential financial information.
- **Regular Infrastructure Assessment and Audit:** Continuous monitoring, assessment, and periodic audits of the infrastructure are necessary to identify and rectify potential vulnerabilities. This proactive approach ensures that the

technology and systems used to store and process financial data are up to date and resilient against cyber threats.

- **Stringent Data Access Controls:** Implementing stringent data access controls is imperative. These controls should enforce strict authentication and authorization mechanisms to ensure that only authorized individuals or entities can access sensitive financial information. This helps mitigate the risk of unauthorized access and data breaches.
- **Carefully Designed Data Management Policies:** Data management policies should be thoughtfully designed to minimize data exposure. By limiting the retention of unnecessary data and implementing data anonymization or encryption where appropriate, organizations can reduce the potential risks associated with accumulating sensitive information.
- **Comprehensive Audit Trails:** Establishing comprehensive audit trails is essential for transparency and accountability. These logs record all actions taken on financial data, creating a clear chain of custody. In the event of any security incident or data breach, these audit trails can help trace the source of the breach and hold responsible parties accountable.

In essence, this multifaceted approach highlights the importance of not only safeguarding financial data but also ensuring that privacy standards are maintained during collaborations. Such measures collectively contribute to the overall security and privacy of financial information in an increasingly interconnected and data driven world.

Capacity Building and Training:

Good infrastructure forms the foundation for capacity building to combat against financial fraud. It is recommended to prioritize investments in cutting-edge infrastructure, manpower training and robust IT systems to excel in financial fraud investigation.

In Australia, UK, USA and in other countries, apart from CPAs, CAs other professionals are entrusted with the responsibility of conducting financial fraud investigations, reflecting the seriousness with which financial misconduct is addressed in these countries. When it comes to forensic accounting and fraud investigations, specialized skills; beyond the scope of traditional CA's are often required. These include in-depth knowledge of forensic techniques, data analytics, cyber forensics and a thorough understanding of fraud detection and prevention methodologies. Therefore, there is a growing recognition of the need for additional education or certifications, such as Masters' or Diploma Program



in Forensic Accounting or any other certified professionals who specialize in fraud investigations.

Some certifications/credentials are recognized internationally as a symbol of excellence in fraud examination. While specific requirements for conducting forensic investigations vary from country to country, CFEs are widely acknowledged as experts in the field and are often allowed to conduct forensic investigations in several countries.

The absence of formal recognition and certification programs in forensic accounting and investigation in India presents several significant issues. It limits the professional development and specialization opportunities for individuals aspiring to become forensic accountants and fraud investigators. This gap in recognition hinders the country's ability to produce a cadre of highly skilled experts in financial fraud detection and prevention.

In the absence of recognized certifications, there may be a lack of clarity and accountability in the field, making it challenging for organizations and law enforcement agencies to identify qualified experts for fraud-related tasks. This can lead to delays and inefficiencies in handling financial fraud cases.

Overall, recognizing and providing certifications in forensic accounting and investigation in India would not only enhance the professional development of individuals but also strengthen the nation's ability to combat financial fraud effectively, maintain financial transparency and protect the interests of businesses and citizens.

Such investments would empower investigators with advanced tools of forensic accounting and auditing. These upliftment would provide secure and efficient environment for handling sensitive financial data and conducting comprehensive investigations. In this rapidly changing digital era, a commitment to investing and upgrading infrastructure is need of the hour for safeguarding financial systems.

Global Standards and Cooperation:

Global standards for financial fraud investigation encompass a set of best practices, guidelines and principles that help ensure consistency, effectiveness and ethical conduct in the field of fraud examination and investigation. While there isn't a single universally accepted standard, there are several international organizations and standards that serve as important references and resources for



professionals involved in financial fraud investigation. Some of these include:

Association of Certified Fraud Examiners (ACFE): The ACFE is a leading global organization that offers the Certified Fraud Examiner (CFE) credential, which is widely recognized as a standard of excellence in fraud examination. ACFE provides a comprehensive Fraud Examiners Manual and Code of Ethics that serve as important references for fraud investigators.

International Standards on Auditing (ISAs): Developed by the International Auditing and Assurance Standards Board (IAASB), ISAs are a set of auditing standards that provide guidelines for conducting financial audits, including procedures to detect and respond to fraud risks. These standards are relevant to forensic accountants and auditors involved in fraud investigations.

ISO 37001: Anti-Bribery Management Systems: This international standard, issued by the International Organization for Standardization (ISO), outlines the requirements for establishing, implementing, maintaining, and improving anti-bribery management systems. While primarily focused on anti-bribery, its principles can be applied in the context of fraud prevention and investigation.

United Nations Convention against Corruption (UNCAC): UNCAC stands as a worldwide anti-corruption treaty that offers a framework for preventing and addressing corruption as well as associated offenses, including financial fraud. It encourages countries to establish effective anti-corruption policies and measures, including those related to investigations.

Financial Action Task Force (FATF): FATF, an intergovernmental organization, establishes global benchmarks for anti-money laundering (AML) and countering terrorist financing (CTF) efforts. These standards are critical for financial investigations involving illicit financial flows.

International Organization of Securities Commissions (IOSCO): IOSCO develops and promotes global standards for securities regulation. Its principles include provisions for market surveillance, fraud detection, and enforcement of securities laws, which are relevant to financial fraud investigations in the securities industry.

National Laws and Regulations: In addition to international standards, each country has its own laws and regulations governing financial fraud investigation, which investigators must adhere to while conducting their work.



FAIS Standards: Recently on 1st July 2023, ICAI has issued Forensic Accounting and Investigation Standards (FAIS) in India. The FAIS are a minimum set of requirements when conducting Forensic Accounting Investigation. But these standards also primarily focus on **qualitative measures** for conducting investigations.

Professionals involved in this field must stay updated with local laws and regulations. Besides, given the global nature of financial crimes, cross-border cooperation is essential to effectively combat these threats. Some agencies like Interpol and FATF enhances global financial fraud investigation through real-time information sharing and cross-border cooperation. The alignment between local and international bodies for sharing information would help the countries to effectively mitigate these issues.

Conclusion

In conclusion, the growing risk of financial fraud calls for a united and technology driven strategy. The rising number of fraud cases emphasize the need for coordinated actions involving law enforcement agencies (LEAs), Chartered Accountants and other stakeholders.

The constraints faced by chartered accountants in forensic investigation are clear. While they excel in financial expertise, navigating the complexities of forensic investigation requires specialized skills in areas like forensics and data analytics, which go beyond their traditional scope. The complexities of modern financial crimes require the need for collaboration with professionals specializing in forensic accounting and forensic auditing.

It is recommended to offer specialized education programs and training to professionals to bridge the gap between traditional accounting practices and the sophisticated techniques required for forensic investigations.

Establishing dedicated “Financial Fraud Investigation Facilities” in regions equipped with advanced tools and expert staff can enhance cooperation among enforcement agencies. A comprehensive approach blending Technology, Policy, Collaboration and Skilled Workforce is pivotal in curbing financial fraud.

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Chapter 15

Questioned Documents Examination - Modern Procedures for Better Efficiency

Dr. Surbhi Mathur¹

Introduction to Questioned Document Examination

“Truth is like a hidden watermark within a document, waiting for the examiner’s light to shine upon it.” Forensic Document Examination is a specialized field within forensic science that involves the examination, analysis, and comparison of documents to establish their authenticity, origin, and content. This discipline is crucial in legal investigations and court proceedings, as it helps determine the validity of documents and can be used to detect fraud, forgery, and other forms of document tampering. Forensic Document Examiners enact a pivotal role in uncovering the obscured narratives within documents and enabling a more accurate apprehension of truth.

Documents are abundant sources of information; its examination can prove to be incremental in providing rich facts about its origin, authorship, & authenticity, thereby helping the investigators to succinctly opine on various aspects pertaining to a crime. The case of *Abdul Karim Telgi @ Lala @ Karim ... vs State on 17 September, 2007*, which unveiled as one of the biggest scams in India that took place in the year 2003, where in Abdul Karim Telgi the mastermind behind the case, managed to commit 30,000 crores a stamp paper scam by using sophisticated tools for counterfeiting stamp papers. Scams like this cripple the economy and result in the slowdown of the economic growth, causing a massive hemorrhage in the economic conditions of the normal citizens of the country.

The aforementioned case indicates the scope and need of introducing, practicing, and implying advanced techniques of document examination which can be used

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in order to prevent and expose document related crimes before they find a chance to become substantial and gain momentum.

The law enforcement agencies of the country frequently deal with documentary evidences in white collar crimes and financial frauds. In order to dissect and probe the evidentiary value of various documentary evidence submitted for examination, document analysis aims to provide expert opinions on various aspects of questioned documents, including handwriting, signatures, typewritten or printed text, alterations, and other physical characteristics. The primary objectives include verifying the authenticity of documents, identifying the authorship of handwriting or signatures, and detecting any alterations or modifications.

With an endeavor to conduct fruitful examination and to gather maximum evidence pertaining to a case, examiners adopt novel methods and tools to investigate various aspects of documentary evidence. Forensic document examiners are frequently called upon to assist in criminal investigations, civil litigation, and various legal matters. They help provide evidence in cases involving identity theft, fraud, forgery, wills and contracts, and many other document-related disputes. To ensure that no damage is done to the evidence non-invasive techniques and procedures are chosen for conducting the analysis. Analytical techniques that are destructive in nature are generally avoided and are only executed in cases where no alternate method for analysis is possible.

The effective and efficient operation of governments, organizations, and societies at large depends on well-informed policy decisions the construct for which depend on the full comprehension of the pertinent facts, figures, studies, and professional opinions of all the stake holders involved in the same. Informed policy decisions not only help in enhancing the credibility of the process but also emphasize the utility and operation of standards that are consistent and reliable to adopt.

Current Landscape of Forensic Questioned Document Examination

Analysis of handwriting is still a key component of document evaluation. However, the examiners nowadays have access to computer-based handwriting analysis tools that can help in recognizing and contrasting handwriting traits. Technology development has resulted in the creation of a vast array of potential outcomes that have provided the society with countless advantages. The nature and methods of crime nowadays have been greatly impacted by the constantly



changing nature of technology. Technological progress can enable the emergence of novel forms of criminal activities. According to a report published by the National Crime Records Bureau (NCRB), 3,432 cases of credit and debit card fraud cases were reported across India in the year 2021, reflecting a rise of almost 20% compared to the previous year. Notably, there was a surge of over 70% in such frauds during 2020. This indicates that over a span of just two years, instances of credit and debit card-related fraud nearly doubled, as highlighted by the report.

As expanding technologies gain momentum, the scientific study of advanced documents, such as digital papers and certificates, presents a significant challenge for the document examiners as they have to adapt their skills to include the examination of electronic documents, such as emails, PDFs, and scanned images. This includes the analysis of metadata, font identification, and digital signatures. A report by RBI was published in Times of India in March, 2018, regarding the increase in digital manipulations of financial documents, loan documents or identity documents resulting in the loss of about 1.6 crores every hour.

The cyber space or the virtual space has become an integral part of our life, providing us a medium to not only browse an abundant array of information but to exercise anonymity, a luxurious privilege that one desperately seeks to afford in today's world. The anonymity provided by the internet can indeed be exploited by criminals to carry out a wide range of illegal activities while evading identification and apprehension.

Cyber bullying, sending anonymous threats and messages on social media, posting antisocial content and spreading of false information are some of the most common examples of illicit actions that are carried out through digital channels. These situations are currently referred to forensic document examiners who evaluate the identity of the person by closely analyzing the language and manner in which online content is presented. The complex examination of sophisticated documents, which encompasses digital files and certificates, presents a significant challenge to investigators. This is due to the fact that tampering with digital documents involves making unauthorized changes to electronic files, intending to deceive, distort information, or attain an unjust advantage. Such actions have become a prevalent strategy among perpetrators who exploit diverse tools to accomplish their goals.

The aforementioned graph illustrates the pattern of registered cases involving economic offenses categorized within the context of the Indian scenario. The numbers presented are alarming and urge the need of developing novel tools and techniques for its prevention.

Manipulating documents using online tools and aids, has led to an increase in the frauds related to identity theft and economic frauds such as bank frauds. Criminals conceal and adopt of the identity of innocent individuals and issue bank cards, loans in their name, with intent to siphon off large sums of money. The examination of such cases has become challenging to document examiners signifying the need to introduce non-conventional techniques to investigate the same. The nature of reported offenses highlights the necessity for a partnership between document and cyber experts. These professionals can collaborate effectively to examine digital documents that have become common nowadays.

Key Technological Advancements

The field of questioned document examination has been considerably impacted by technological breakthroughs, which have improved the efficiency and accuracy of document analysis. With the advanced technology, the security characteristics of current currency, passports, visas, and other official papers can be efficiently examined and verified. Digital cameras with high resolution and image software have dramatically enhanced our capacity to photograph and record specifics in contested documents. This includes capturing the texture of paper, ink, and handwriting characteristics with exceptional clarity.

Modern scanners enable the creation of highly detailed digital copies of documents, making it simpler to study and compare documents, especially when dealing with complex graphics, security features, or subtle adjustments. Inks, paper, and other materials used in documents can all be examined using spectroscopy methods like as infrared and ultraviolet spectroscopy. These techniques can accurately reveal altered or hidden information as well as ink composition.

In order to create and analyze behavioral profiles of authors based on their handwriting and signatures, specialized graphometric software are used. This program gives examiners unbiased evidence to back their findings.

Modern digital forensic tools are used to examine scanned copies, emails, digital signatures, and electronic documents. These technologies can reveal metadata,



repair fading or damaged documents, analyze font usage, and find digital alterations or forgeries. Examiners can more effectively compare questioned handwriting or text with known standards with the use of modern software applications made especially for document examination. These tools are capable of detecting minute variations and similarities.

In the age of Artificial Intelligence, machines have become intelligent and are endowed with the capacity to learn, reason, and make decisions. AI has paved the way to revolutionize various fields and open new avenues for research and innovation. The integration of Artificial Intelligence (AI) into the field of document examination has resulted in enhancing the efficiency, accuracy, and scope of analyzing documentary evidence submitted for examination. AI tools are used for automated data extraction, segregation, classification, and flagging the content found in documents. With latest AI tools it is possible for examiners to examine and process a large number handwriting samples for authorship analysis.

The potential of AI tools in recognizing patterns is used to detect anomalies in documents which can in turn help in evaluating fraudulent activities. These algorithms are also capable in identifying inconsistencies in handwriting, ink patterns, and in the layout of various documents to detect possible forgeries or alterations. The utilization of AI can lead to enhanced speed and efficiency in various aspects of the examination process and can thus serve as a crucial asset to document examiners.

In addition, methods like 3D topography mapping are employed to examine papers and inks and to examine the surface of documents, revealing impressions from various writing instruments, handwriting pressure, and ink layering.

To help document examiners in the field, portable gadgets and mobile apps have been created. These tools enable speedy inspection of documents at crime scenes or during investigations.

The effectiveness and efficiency of the questioned document examination have increased because to these technological developments. However, in order to uphold the highest standards in their industry, forensic document examiners must keep abreast of the most recent technology and procedures. Top of Form

Policy Recommendations

Data Management and Sharing

Regardless of the nature of the case, confidentiality and privacy of data are integral components of any investigation. Documents inherently contain data, and it's crucial to recognize that any type of data present within a document should be handled with confidentiality. Maintaining the secrecy and security of data within documents is of paramount importance and requires meticulous care and attention. A global structured policy regarding the same needs to be proposed which shall serve to be beneficial in ensuring the adherence and compliance of legal and ethical standards that is fundamental in preserving the integrity of the data can lead to seamless sharing of data for cross-border data sharing.

High-quality scanning or imaging tools can be used to create digital reproductions of physical documents, which can then be safeguarded in a controlled environment to avoid tampering or damage. The integrity of the file should be guaranteed by maintaining an appropriate chain of custody. It is important to note the specifics of the document's pertinent metadata, such as the date, source, and location. Additionally, a powerful cataloging system needs to be developed in order to effectively handle and retrieve papers during the inspection process.

A digital document management system should be developed for the organizing and storage of the electronic file. This system can employ uniform file naming conventions and folder architecture for simple access and retrieval of the needed data. To prevent data loss, regular backups of both physical and digital documents should be made. To reduce the risk of loss from disasters, backup copies should be kept in safe, off-site locations.

In order to preserve sensitive information, the examined data and findings can be communicated with other specialists or stakeholders involved in the inspection process utilizing secure file-sharing platforms or encrypted communication methods. You can establish strict access controls to restrict who can read, edit, or share sensitive documents. To prevent unwanted access, the digital data can be encrypted and robust authentication techniques can be applied.

Quality Control and Standardization

The competency of laboratories relies on the adherence and implementation



of standard operating procedures and policy frameworks that are followed in order to assure quality with regards to the accuracy, reliability, and consistency in the analysis and authentication of documentary evidences. Establishing a uniform global framework for quality assurance and management in document examination can have numerous benefits for enhancing the quality metrics and competency of the laboratory. A standard policy can also offer consistency in examination processes, methodologies, and procedures across different labs and regions. This consistency minimizes variations in results and interpretations, leading to greater accuracy and reliability in document analysis.

Such a framework can contribute to standardization, competence, and overall effectiveness by guaranteeing quality Metrics Improvement, competency enhancement, implementation of latest techniques and tools that can lead to the continuous development of the field and bestow global recognition. Time to time peer reviews and audits should be conducted to identify and address potential errors.

Research and Development Funding

Research and development lead to innovation, which is the essence of progress. The field of Document examination is very versatile as documentary evidence submitted for examination could be in the form of written, printed, or electronic piece. The examination process has become notably more complex due to the continuous emergence of new and challenging cases. This complexity is attributed to rapid technological advancements and widespread access to these technologies by the general population.

Research can contribute in developing cutting edge tools and solutions to the problems encountered by the examiners thereby advocating the need to propose various projects that can result in the scientific discovery of credible methods best suited for examination.

Interdisciplinary Collaboration

The development of comprehensive strategies is a result of comprehensive collaborative work between forensic scientists, legal experts, and policymakers. Given the multifaceted nature of the field, an interdisciplinary collaboration among experts from various disciplines offers the ground to discern and include all the laterals that might be crucial to consider in case of document examination. Such profitable collaborations can significantly lead to the

improvement of analysis and accuracy of forensic examinations, fostering a thorough comprehension, thereby contributing to the generation of stronger and more credible examination outcomes.

Ethical and Legal Considerations

Privacy Protections

Upholding ethical standards and values in all decision-making and actions can serve as an integral facet in promoting trust, transparency, and responsible conduct. Robust strategies that validate and ensure the safeguarding of privacy must be universally standardized and embraced to thwart unauthorized access to sensitive information. Bringing uniformity in such policies at a global level can address paramount topics that pertain to the measures taken to prevent unauthorized access, data retention and use.

Regulation of Emerging Technologies

An amalgam of technological advancements with progressing research and development has resulted in the emergence of various novel technologies that remain on the horizon awaiting its implementation and regulation. A framework regulating the emerging technologies and its use can ensure its responsible use and prevent unintended consequences. The development of such policies and framework would require an interdisciplinary collaboration advocating the need of joint ventures that can prove to ensure precision and dependability.

The framework laid out for the regulation of emerging technologies shall offer a check on the new technologies and impart pre-requisite knowledge to examiners over the use of right technologies that are credible and consistent for examination.

Capacity Building and Training

Infrastructural Development

Infrastructural development is an essential component required for the development of laboratories, it remains the foundation upon which the lab governs and equips the laboratory with the necessary structure, including equipment, facilities, and IT systems to upgrade the productivity of the lab. An investment in state-of-the-art laboratory infrastructure is also synonyms to up scaling the lab with modern cutting-edge technologies that can cater to multifaceted needs of the industry.



Workforce Development

Intensive training and certification programs for examiners not only boost their understanding of the latest tools and methodologies in the field but also help in cultivating the essential skills and expertise required for document examination.

Regular training updates should also be provided to keep examiners up-to-date with the latest techniques and technologies. A skilled workforce shall be capable of handling advanced technologies that are implemented worldwide and can help in increasing the overall competitiveness of examination laboratories.

Public Awareness Programs

Change initiates through awareness and awakens the need for it. Public awareness programs play a role in endorsing and sharing knowledge within the domain. They hold significance as reliable information sources. Such programs play a role in stimulating creativity among individuals, culminating in fresh ventures and innovative approaches to examination of disputed documents. Additionally, they facilitate the exchange of advantages, drawbacks, and the broader consequences of nurturing a society with enhanced knowledge.

Such programs help in fostering the exchange of ideas and knowledge among individuals from various backgrounds, such as law enforcement, academia, and industry. This collaboration can put emphasis in the exchange of ideas and the development of comprehensive strategies for tackling document-related challenges.

International Cooperation

Global Standards

Forensic document examiners (FDEs) adhere to established guidelines for their methodologies and expertise. The Scientific Working Group for Forensic Document Examination (SWGDOC) has formulated a comprehensive set of 21 standards, which have been published by ASTM International. These standards cover a wide range of aspects within the domain of Forensic Document Examination, ranging from the general Scope of Work of FDEs to specific standards for analyzing altered documents and other specialized examinations.

Starting in 2012, the ASTM standards that pertain to (Forensic document examiners) FDEs have been gradually replaced by standards formulated by

SWGDOC, as the former standards expire. The American Board of Forensic Document Examiners (ABFDE) maintains its role in certifying the proficiency of FDEs through rigorous testing and certification.

The availability of global standards and procedures help in establishing a common framework and methodology for document examination across different jurisdictions and organizations. This ensures that experts follow consistent procedures, methodologies, and terminology, leading to more reliable and accurate results, also ensuing in setting up guidelines and procedures for data sharing, and collaboration to facilitate seamless cooperation across borders.

Joint Investigative Efforts

Joint investigative efforts by professionals to examine questioned documents in cross border crimes shall harness the expertise, skill and resources between countries to enhance the efficiency and accuracy with which documentary evidences are scrutinized. Such efforts should be encouraged

Conclusion

Forensic questioned document analysis involves the thorough examination of documentary evidence to delve into the vast information that is presented through it. Scientific principles and techniques are applied to examine, compare and interpret the evidence at hand to determine their authenticity, origin, and signs of any potential alterations.

Questioned document examiners examine elements like handwriting characteristics, ink properties, paper make, printing techniques used, and signs of document aging to offer expert opinions regarding the authenticity of documents and identify indications of counterfeiting, alteration, or tampering. Technological progress has sparked a trend in the way document frauds are committed nowadays.

The use of e-documents and certificates has now become prevalent, criminals make use of sophisticated tools to manipulate and alter these documents to commit financial frauds. Criminals also exploit the cyber space to commit crimes by concealing their identities, making it hard for the investigators to apprehend them. Authorship identification through the language style and manner is carried out by document examiners to establish the identity in such cases.

Challenges with respect to investigating digital documents and the necessity to develop pertinent techniques to investigate the same has become the need of the hour. The use of AI in document examination shall revolutionize the way examinations are conducted today by helping in the timely analysis of document with high accuracy.

Research and Development are driving forces for innovation and progress, joint ventures promoting the same shall be encouraged through framing global standard policies and framework that shall help in protecting the privacy of the data, preventing unauthorized access, whilst describing data retention and use.

Interdisciplinary collaborations, work force development, infrastructural development and joint investigative efforts promote the overall competency of laboratories. Proficiency testing and quality assurance can be regulated by standardized guidelines which shall assure in demonstrating the aptitude of the laboratory.

Global standards in document examination ensure consistency, reliability, and credibility in the field of forensic analysis and legal proceedings. They help in establishing clear and measurable standards or specifications that must be met to generate reliable results. These standards are often based on the current challenges and requirements, industry best practices, and regulatory guidelines.

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सर्वे भद्राणि पश्यन्तु ।
मा कश्चित् दुःख भाग्भवेत् ॥

May all be happy
May all be healthy
May all see auspiciousness
May none suffer, Peace be unto all.



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