

Forensic Medicine and the Integration of Traditional and Non-Traditional Approaches: A Global Literature Review

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Abstract

Forensic medicine serves as a critical intersection between medical science and the legal system, providing essential insights into cause of death, injury mechanisms, and identification of individuals. Traditionally grounded in pathology, toxicology, and molecular biology, the field has evolved with advances in scientific methodologies. Recently, interest has emerged in integrating non-traditional approaches including natural compounds such as resveratrol, curcumin, aloe vera, L-theanine, black cumin seed oil, pine bark extract, and velvet bean into forensic applications. This literature review evaluates both traditional and non-traditional approaches in forensic medicine, emphasizing their global relevance, biochemical mechanisms, and potential contributions to postmortem preservation, toxicological interpretation, and practitioner well-being. The review also examines the physiological and pathological aspects of drowning as a model forensic condition. Findings suggest that while traditional methods remain foundational, emerging natural compounds may offer complementary benefits in tissue preservation, oxidative stress reduction, and stress management. However, further validation and standardization are required to ensure scientific reliability and legal admissibility.

Introduction

Forensic medicine is a multidisciplinary field that determines the cause and circumstances of death by integrating medical, scientific, and legal principles (Jain 46). Alongside traditional methods, growing interest in natural compounds such as vitamins, minerals, and plant-based substances is expanding its scope, particularly in tissue preservation and postmortem care. Compounds like black cumin seed oil, resveratrol, curcumin, and aloe vera show potential in reducing oxidative stress, limiting inflammation, and preserving tissue integrity, thereby supporting the quality of forensic evidence (Amer; Behl, Amarnath, and Sharma; Shakeri et al.). Natural compounds may also support forensic professionals. L-theanine can help manage stress and improve focus, while pine bark extract may protect biological samples from oxidative damage. Velvet bean, a source of L-DOPA, offers potential insights into neurological changes in forensic cases (Sohail et al.; Gafner et al.; Carlier et al.). Overall, integrating natural compounds with traditional methods provides a more comprehensive and innovative approach, enhancing both forensic analysis and practitioner well-being.

Background and Significance

Forensic medicine is a specialized field that supports legal investigations involving injuries, accidents, and deaths by determining cause of death, identifying individuals, and assessing trauma (Jain 47). It serves as a critical link between medical science and the legal system, providing evidence for criminal cases, accident analysis, and mass disaster response (Jain 48; Arica et al. 62). Legal standards vary across jurisdictions, requiring forensic professionals to adapt to different regulations and emphasizing the need for global standardization. As the field evolves, it integrates both traditional and emerging approaches to improve accuracy and efficiency (Arica et al. 64). Traditional methods such as autopsies, toxicology, fingerprinting, and DNA analysis remain foundational (Barik 18). Meanwhile, non-traditional approaches including natural compounds, zeolites, and silica offer complementary insights that enhance preservation and analysis. Together, these methods create a more comprehensive and adaptable framework for forensic investigations.

Purpose of the Research

This research explores forensic medicine from a global perspective by integrating traditional and non-traditional approaches. It examines natural compounds such as L-theanine, black cumin seed oil, curcumin, resveratrol, aloe vera, pine bark extract, and velvet bean for their potential roles in tissue preservation, postmortem changes, stress management, and forensic accuracy (Carlier et al.). While forensic medicine relies on established methods like autopsies, toxicology, DNA analysis, and fingerprinting (Akhgari, Noushin, and Fariba; Arica et al. 63), this study evaluates whether natural substances such as vitamins, minerals, plant compounds, zeolites, and silica can enhance preservation, microbial control, and environmental analysis. Sunlight also contributes to sterilization and decomposition processes (Barik 19; Grela et al.). Although promising, these approaches require strict validation and must meet legal and ethical standards. Overall, combining traditional and emerging methods creates a more comprehensive and adaptable forensic framework.

An Overview of Forensic Medicine

Definition and Purpose of Forensic Medicine

Forensic medicine, or forensic pathology, is a multidisciplinary field that applies medical knowledge to legal investigations involving crime, accidents, and unexplained deaths (Fahmy 38). It serves as a bridge between healthcare and the legal system, focusing on determining cause of death, identifying injuries, and assisting in human identification to support justice. A key component is the postmortem examination, where autopsies help determine cause and time of death using indicators such as rigor mortis, livor mortis, and insect activity (Barik 17; Fahmy 73). Identification methods include DNA, fingerprints, and dental records, while injury assessments support both criminal and civil cases (Fahmy 257). The field also includes forensic toxicology, which detects drugs, alcohol, and poisons, as well as specialized areas like sexual assault investigations, child abuse assessment, and mental health evaluations. Overall, forensic medicine provides essential scientific evidence and expert analysis to support legal decision-making.

Historical Development

The history of forensic medicine spans centuries, evolving alongside medical and legal systems (Prosono). Its origins date back to ancient civilizations, including early postmortem practices in Ancient Egypt around 3000 BCE (Baymakov et al. 7753; Ubelaker). Greek and Roman contributions, especially Hippocrates' emphasis on observation, shaped early scientific approaches, though progress slowed in medieval Europe due to religious restrictions. The Renaissance and Enlightenment revived scientific inquiry, advancing anatomy and tools like the microscope. The 19th century introduced key developments such as ballistics, fingerprinting, and standardized autopsies, establishing forensic pathology as a formal discipline. In the 20th century, DNA analysis revolutionized identification and criminal investigations. Today, forensic medicine is a multidisciplinary field integrating pathology, toxicology, anthropology, and psychiatry to support modern legal systems.

Role of Forensic Medicine in Criminal and Civil Courts

Forensic medicine plays a vital role in both criminal and civil courts, contributing to justice, the protection of individual rights, and

the resolution of legal disputes (Riversband Gregory 2). This section explores its various functions within these legal contexts and highlights various methods by which it uses expert analysis and testimony.

Criminal Courts

Forensic medicine plays a key role in criminal courts by providing scientific analysis and expert evidence for legal investigations (Rivers and Gregory 2–3). Professionals determine cause of death, analyze injuries, evaluate evidence, and conduct toxicology testing. Autopsies are central, helping reconstruct events and identify contributing factors in suspicious cases (Szeremeta et al.; Akhgari, Noushin, and Fariba). Toxicology detects drugs, alcohol, and poisons, while ballistics links firearms to crimes. DNA analysis has revolutionized investigations by identifying suspects and solving cold cases (Rivers and Gregory 7). Additional tools include trace evidence analysis and forensic entomology for estimating time of death. Forensic experts also serve as witnesses in court, explaining findings to support legal decisions, often influencing case outcomes (Rivers and Gregory 6).

Civil Courts

Forensic medicine plays an important role in civil courts by helping resolve disputes related to liability and compensation (Rivers and Gregory 4). Experts assess injuries in cases such as medical malpractice, workplace accidents, and vehicle incidents, often influencing compensation outcomes. They also contribute to child custody and abuse cases through psychological evaluations, and to document analysis by detecting forgery in wills, contracts, and financial records (Baymakov et al. 7753). Additionally, forensic accountants investigate fraud, while forensic engineers analyze accidents and structural failures to determine liability. Together, these disciplines provide critical evidence to support fair outcomes in civil cases (Rivers and Gregory 38, 297).

Integrating Natural Compounds in Forensic Medicine

Black Cumin Seed Oil in Forensic Healing

Black cumin seed oil, derived from *Nigella sativa*, has a long history in Ayurvedic, Middle Eastern, and North African medicine (Choudhary, Seth, and Lata). Its key bioactive compounds thymoquinone, thymol, and thymohydroquinone provide antioxidant, anti-inflammatory, antimicrobial, and immunomodulatory effects, supporting its broad therapeutic use. In forensic medicine, these properties offer promising applications. Its antioxidant activity may help slow postmortem tissue degradation by reducing oxidative stress, while its anti-inflammatory effects may influence cytokine activity and improve the accuracy of postmortem analyses. Additionally, its antimicrobial properties may limit microbial activity during decomposition, aiding in more reliable estimations of time and cause of death. Black cumin seed oil may also be detectable in biological samples, making its toxicological relevance important in forensic investigations. Overall, it represents a potential complementary tool for preserving tissue integrity and enhancing analytical reliability, while bridging traditional knowledge with modern forensic science (Choudhary, Seth, and Lata).

Resveratrol: A Natural Compound in Forensic Pathology

Resveratrol, a natural compound found in grapes and berries, has gained attention for its potential health and forensic applications due to its strong antioxidant properties (Amer). In forensic pathology, it may help reduce postmortem oxidative stress, a major contributor to tissue degradation through reactive oxygen species (ROS), lipid peroxidation, and protein damage. By neutralizing free radicals and supporting antioxidant defenses, resveratrol may help preserve tissue integrity, particularly in cases involving delayed discovery or harsh environmental conditions (Amer).

In addition to its antioxidant effects, resveratrol's anti-inflammatory properties may further help limit postmortem tissue changes, improving the accuracy of forensic analyses. Its potential to protect DNA integrity is especially significant, as postmortem DNA degradation can compromise identification and genetic analysis. Resveratrol may also influence autophagy, helping maintain cellular structures and improving the preservation of histological evidence (Amer). Furthermore, its neuroprotective properties suggest potential value in cases involving neurological injury, where preserving tissue integrity is critical for accurate forensic interpretation (Carlier

et al.). Overall, resveratrol represents a promising adjunct in forensic medicine, particularly in preserving biological evidence and supporting reliable analysis.

Curcumin: Forensic Applications and Beyond

Curcumin, a polyphenol derived from turmeric, is well known for its anti-inflammatory and antioxidant properties and has emerging relevance in forensic pathology (González et al.). Because inflammation plays a significant role in postmortem changes and can complicate autopsy analysis, curcumin's ability to modulate inflammatory pathways makes it a valuable area of investigation (Carlier et al.). At the molecular level, curcumin influences key signaling pathways, such as NF- κ B, reducing the expression of pro-inflammatory genes and cytokines that contribute to tissue degradation after death (Ansari et al.). By limiting inflammation, it may help preserve tissue integrity and improve the accuracy of postmortem assessments. Curcumin may also support tissue preservation through its interaction with cell membranes, helping stabilize cellular structures that are typically disrupted during decomposition. Its antioxidant activity further contributes by neutralizing free radicals and reducing oxidative damage, which can otherwise accelerate tissue breakdown. Additionally, curcumin's potential role in modulating autophagy suggests it may help regulate cellular degradation processes, offering further support in maintaining tissue structure during postmortem intervals. Overall, curcumin presents a promising complementary approach for improving tissue preservation and analytical clarity in forensic investigations.

Aloe Vera: Healing Properties in Postmortem Care

Aloe vera, long recognized for its healing properties, has gained attention in forensic pathology for its potential role in postmortem tissue preservation (Shakeri et al.). Rich in bioactive compounds such as polysaccharides, enzymes, and amino acids, its gel exhibits anti-inflammatory, antimicrobial, and soothing effects that may help reduce postmortem tissue degradation. Its strong moisturizing properties may prevent desiccation, preserving tissue structure and pliability for more accurate histological analysis during autopsies. Aloe vera's ability to reduce inflammation may also limit postmortem alterations, improving the clarity of forensic assessments. Additionally, its antimicrobial effects may help inhibit microbial activity that contributes to decomposition, while its interaction with postmortem processes such as livor mortis may offer further insights into tissue changes after death. Overall, aloe vera presents a promising complementary approach to enhancing tissue preservation and analysis in forensic investigations.

L-Theanine in Forensic Stress Management

Forensic professionals often face high levels of stress due to exposure to emotionally intense and demanding environments, which can negatively impact mental health and job performance (Sohail et al.). As a result, effective stress management strategies are essential. L-theanine, an amino acid found in tea, has gained attention for its ability to promote relaxation without causing sedation. L-theanine supports a state of relaxed alertness by increasing alpha brain wave activity and modulating neurotransmitters such as GABA and serotonin, which are important for mood regulation and anxiety reduction (Sohail et al.). These effects may help forensic professionals better manage stress during high-pressure situations. In addition to reducing stress, L-theanine may offer anxiolytic and neuroprotective benefits, supporting emotional balance and resilience in individuals regularly exposed to traumatic events. Its antioxidant properties may also help protect against cognitive fatigue and burnout associated with chronic stress. Overall, L-theanine represents a promising natural approach to supporting mental well-being in forensic professions (Sohail et al.).

Pine Bark Extract: An Antioxidant Approach in Forensic Science

Maintaining the integrity of biological evidence is a major challenge in forensic science, particularly due to oxidative stress caused by reactive oxygen species (ROS), which can damage DNA, proteins, and other biomolecules (Gafner et al.). Pine bark extract, derived from *Pinus pinaster*, is rich in polyphenols such as proanthocyanidins and is well known for its strong antioxidant properties, making it a potential tool for protecting forensic samples. Research suggests that pine bark extract can neutralize ROS and help preserve the molecular structure of biological evidence, including blood, tissue, and DNA. By reducing oxidative damage such as strand breaks and base modifications it may improve sample stability and the reliability of forensic analyses (Gafner et al.). Its effectiveness across differ-

ent sample types highlights its potential as a complementary preservation strategy. However, its use also requires careful toxicological consideration. The presence of bioactive compounds may influence analytical results, making it important to understand its metabolism, detectability, and potential effects on forensic interpretation. Overall, pine bark extract presents a promising yet complex option for enhancing evidence preservation, warranting further investigation within forensic applications (Gafner et al.).

Velvet Bean: Neuroprotective Potential in Forensic Cases

Forensic medicine has long sought innovative approaches to address trauma, particularly head injuries, which often result in significant neurological damage (Gafner et al.). Velvet bean (*Mucuna pruriens*) has gained attention due to its neuroprotective properties, largely attributed to L-DOPA, a precursor to dopamine essential for cognitive and motor function. By supporting dopamine production, velvet bean may help restore neurotransmitter balance and reduce the effects of traumatic brain injury. Its potential relevance in forensic neuropathology lies in its ability to influence neuroinflammation, oxidative stress, and neuronal survival. These effects may help preserve neural tissue and improve understanding of postmortem brain changes following trauma. However, its integration into forensic analysis requires careful evaluation to ensure compatibility with existing techniques such as histological and molecular assessments (Gafner et al.). From a toxicological perspective, velvet bean presents both opportunities and challenges. While it may offer neuroprotective benefits, excessive exposure could disrupt neurotransmitter balance and affect neurological function, complicating forensic interpretation. Additionally, detecting its bioactive compounds in biological samples may require specialized analytical methods. Overall, velvet bean represents a promising yet complex factor in forensic investigations, particularly in cases involving neurological injury (Gafner et al.).

Drowning: Mechanisms and Physiological Changes

Drowning is a complex global health issue involving environmental and physiological factors (Marella et al. 919–920). It occurs when water enters the respiratory system, leading to hypoxia and asphyxia. The type of water influences outcomes: seawater (hypertonic) draws fluid into the lungs, while freshwater (hypotonic) can cause alveolar collapse. Physiological responses include hypoxemia, pulmonary vasoconstriction, myocardial depression, and increased capillary permeability, often resulting in pulmonary edema and impaired oxygen exchange (Marella et al. 921; Bierens et al. 147). Disruption of pulmonary surfactant further contributes to alveolar collapse and respiratory failure. Forensic diagnosis is complicated by factors such as trauma, hypothermia, or pre-existing conditions. Investigators rely on signs like “washerwoman’s skin,” lung findings, and tools such as diatom analysis and blood chemistry to confirm drowning and differentiate water types. Understanding these mechanisms is essential for accurate cause-of-death determination and improved forensic investigation.

Clinical and Pathological Diagnosis of Drowning & Evidence of Immersion

Accurate diagnosis of drowning requires integrating clinical signs with pathological findings (Marella et al. 924). Early clinical indicators may include impaired coordination, gasping, and cyanosis, though drowning can occur with minimal visible distress. Confirmation relies on pathology, with key findings such as pulmonary edema, frothy airway fluid, and alveolar damage. The presence of diatoms and other tissue changes can further support evidence of water aspiration. Advanced methods like postmortem CT (PMCT) and molecular analysis have improved diagnostic accuracy. Evidence of immersion is also critical. Common signs include “washerwoman’s skin” from prolonged water exposure, skin separation, and postmortem bloating due to gas formation. Additional findings such as emphysema aquosum, Paltauf’s spots, and environmental injuries from aquatic exposure help establish submersion and estimate timelines. Together, these clinical, pathological, and environmental indicators provide a comprehensive framework for determining drowning and reconstructing the circumstances of death.

Reasons for Death in Bodies Recovered from Water

Forensic investigations of bodies recovered from water must consider multiple causes of death, not just drowning. Natural conditions such as myocardial infarction or hypothermia may lead to collapse and secondary submersion, making it essential to distinguish

primary drowning from preexisting medical events. Trauma from accidents or environmental factors can also contribute, requiring careful evaluation of medical history, injuries, and scene context. Assessment of injuries is critical in determining whether trauma occurred before or after submersion. Preexisting injuries such as fractures, head trauma, or signs of assault or self-harm may impair survival in water, while postmortem changes like “washerwoman’s skin,” emphysema aquosum, and Paltauf’s spots may support drowning. Environmental damage or animal activity must also be differentiated from antemortem injuries. Overall, combining medical, pathological, and environmental evidence allows forensic professionals to accurately determine cause of death and reconstruct events in aquatic cases.

Traditional Approaches in Forensic Medicine

Postmortem Examinations and Procedures

Postmortem examinations, or autopsies, are a fundamental component of forensic medicine. They involve a detailed inspection of the body to determine the cause and manner of death. Conducted by forensic pathologists, these examinations are critical in criminal investigations, legal proceedings, and public health, providing essential insights into the circumstances surrounding death.

Postmortem Examination Process

A postmortem examination begins with an external inspection, where the pathologist assesses visible injuries, abnormalities, and signs of disease. This is followed by an internal examination, typically involving a Y-shaped incision and the systematic removal and analysis of organs and tissues to identify causes of death.

Types of Autopsies:

- ***Clinical Autopsy:*** Conducted in hospitals to understand disease and treatment outcomes.
- ***Forensic Autopsy:*** Performed in suspicious or unexplained deaths to determine cause and manner of death.
- ***Virtual Autopsy:*** Uses imaging (CT/MRI) to examine the body non-invasively.
- ***Limited Autopsy:*** Focuses on specific body areas when the cause of death is partially known.

Importance of Postmortem Examinations

Postmortem examinations are essential in forensic medicine for determining the cause and manner of death, supporting criminal investigations, and ensuring justice. They also contribute to medical research and public health by providing insights into disease processes and mortality trends (Akhgari, Noushin, and Fariba). Additionally, autopsies play a key role in legal and insurance matters by helping establish liability in disputes such as wrongful death or malpractice cases. In mass disasters, they are crucial for victim identification and understanding the circumstances surrounding large-scale fatalities.

Non-Traditional Approaches in Forensic Medicine: Use of Vitamins

Forensic medicine continues to evolve by incorporating non-traditional approaches alongside established methods such as DNA analysis and autopsies. One emerging area is the use of vitamins as forensic tools. Vitamins, essential for normal biological function, can serve as biomarkers that provide insight into an individual’s health, lifestyle, and potential exposures (De Giuseppe et al.; Huestis et al.). Changes in vitamin levels may indicate drug use, poisoning, or malnutrition, aiding forensic investigations. In particular, vitamin analysis can help detect substance abuse, as certain drugs affect vitamin metabolism. For example, vitamin C may be used to alter urine test results, and its presence can provide clues in toxicological analysis (Byard and Hamish). Overall, vitamins offer a complementary approach for enhancing forensic investigations.

Detecting Nitrous Oxide Abuse

Vitamins can serve as biomarkers in substance abuse cases, including nitrous oxide (N₂O) misuse. Long-term N₂O use can lead to vitamin B12 deficiency, which is essential for red blood cell production and nervous system function. Significantly low B12 levels may

act as an indirect indicator of N₂O abuse, helping forensic and medical professionals identify at-risk individuals and support investigations.

Vitamins in Drug and Poison Detection

In forensic medicine, vitamins can serve as useful biomarkers for detecting drug use and toxic exposures. Certain substances can alter vitamin metabolism, and changes in vitamin levels may provide indirect evidence of exposure (Huestis et al.; Rivers and Gregory).

Vitamin C and Drug Testing

Vitamin C (ascorbic acid) has been studied in drug testing because some individuals attempt to use it to mask drug presence in urine. Elevated vitamin C levels may raise suspicion of test manipulation, although they are not definitive proof, as levels can vary based on diet and metabolism (Byard and Hamish).

Vitamin B12 and Nitrous Oxide Abuse

Vitamin B12 analysis is particularly relevant in cases of nitrous oxide misuse. Prolonged exposure can impair B12 metabolism, leading to deficiency and associated neurological effects. Low B12 levels, along with clinical findings, may serve as indirect indicators of nitrous oxide abuse in forensic investigations (Cappello et al.).

Vitamins in Malnutrition Assessment

Malnutrition, resulting from inadequate nutrient intake, is a major global health issue and a key focus in forensic investigations (Cappello et al.). Vitamin levels especially B vitamins serve as important biomarkers for assessing nutritional status and identifying cases of abuse, neglect, or deprivation. Deficiencies detected through blood, urine, or tissue analysis can provide critical evidence linking malnutrition to legal cases (De Giuseppe et al.). Vulnerable populations, such as children and the elderly, are particularly affected, often showing signs like developmental delays or cognitive decline. In forensic contexts, vitamin analysis can also reveal nutritional deprivation in cases of captivity or humanitarian crises. Techniques such as HPLC and mass spectrometry ensure accurate measurement, making vitamin analysis a valuable tool in both forensic and public health evaluations.

Vitamins in Sudden Unexplained Deaths

Sudden unexplained deaths present significant challenges in forensic medicine, as causes are often not evident through external examination (Kordrostami et al. 6). Vitamins, as indicators of health and metabolism, can provide valuable clues in these cases (De Giuseppe et al.; Byard and Hamish). Analysis of vitamin levels in postmortem samples may reveal deficiencies or toxicities linked to underlying conditions. For example, vitamin D deficiency may contribute to skeletal weakness or falls, while low vitamin B12 levels may indicate neurological dysfunction (Cappello et al.). Conversely, excessive intake of certain vitamins, such as A or D, can lead to toxicity and may also play a role in sudden death. Vitamin imbalances may also reflect undiagnosed chronic diseases, such as kidney disorders affecting vitamin metabolism. However, interpretation is complex, as postmortem changes and individual variability can influence results. Therefore, vitamin analysis must be used alongside toxicology, histology, and clinical findings. Overall, a multidisciplinary approach is essential to effectively use vitamin data in uncovering causes of sudden unexplained deaths.

Role of Minerals in Postmortem Examinations

In addition to traditional methods, minerals are increasingly recognized as valuable tools in forensic medicine (Ferrara et al.). Analysis of mineral composition in tissues can provide insight into an individual's life history, environmental exposure, and circumstances surrounding death. Minerals can help determine geographic origin, as their presence in the body reflects regional variations in soil, food, and water. Techniques such as strontium isotope analysis allow forensic experts to trace where an individual lived or traveled by comparing tissue samples to geological data (Ferrara et al.). Mineral analysis can also reveal exposure to toxins such as lead or arsenic. Elevated levels in bones or teeth may indicate chronic exposure or poisoning, offering important evidence in forensic investigations.

Overall, minerals provide a valuable complementary approach for understanding identity, environment, and cause of death.

Herbal and Plant-Based Solutions in Forensic Investigations

Forensic medicine traditionally relies on methods such as autopsy, toxicology, and DNA analysis, but non-traditional approaches are expanding the field. Herbal and plant-based compounds, long used in traditional medicine, are now being explored for their unique chemical properties, which can provide valuable insights in forensic investigations (Ahmed and Nagham 3102).

Applications in Toxicology

Herbal and plant-based compounds are an emerging focus in forensic toxicology, aiding in the identification of substances that cause injury or death (Rojek et al.). Many plants contain toxic compounds detectable in biological samples using techniques like GC-MS, HPLC, and phytochemical analysis (Ahmed and Nagham 3103). These methods are essential in cases of accidental or intentional poisoning, helping determine exposure, clarify intent, and support legal investigations. Overall, plant-based toxicology provides valuable insight into both toxin identification and the circumstances surrounding poisoning cases.

Identification of Plant-Based Poisons

Many plants, such as deadly nightshade (*Atropa belladonna*), oleander (*Nerium oleander*), foxglove (*Digitalis purpurea*), and yew (*Taxus* spp.), contain toxic compounds capable of causing serious harm or death. These toxins, including alkaloids and cardiac glycosides, can disrupt vital functions such as heart activity and neurotransmission. In forensic investigations, identifying these compounds in biological samples is essential for determining poisoning as a cause of death. Using advanced analytical techniques, forensic scientists analyze chemical profiles in tissues and fluids to detect plant-based toxins and establish their role in injury or death.

Herbal and Plant-Based Substances in Drug Facilitation

Plant-based substances are increasingly recognized in drug-facilitated crimes such as sexual assault and robbery (Pan et al.). Compounds from sources like cannabis, psilocybin mushrooms, and certain herbal supplements can impair judgment, memory, and motor function, making victims more vulnerable. Because many of these substances are also used recreationally or medicinally, their misuse can be difficult to detect. These substances can cause effects ranging from mild euphoria to severe disorientation, memory loss, and loss of consciousness. Their use without consent, often through contaminated food or drinks, poses significant challenges for forensic investigations. Detection relies on toxicological analysis of biological samples using techniques such as GC-MS and LC-MS, as well as examination of items like drink containers or food remnants. Identifying these compounds is critical for confirming exposure, supporting victims, and prosecuting perpetrators.

Seed, Root, and Plant Extracts in Identifying Toxins and Poisons

Seed, root, and plant extracts are valuable tools in forensic toxicology due to their rich phytochemical composition. Many plants contain toxic compounds that can be detected in biological samples, helping forensic scientists identify poisoning cases and determine cause of death. Techniques such as GC-MS and HPLC are commonly used to analyze these compounds, allowing for accurate identification and quantification. Extracts can also serve as reference standards when comparing toxic substances found in postmortem samples. Plants like deadly nightshade, castor bean, and foxglove are notable for their highly toxic properties. These extracts are also relevant in drug-facilitated crimes, where plant-derived toxins may be used to incapacitate victims. However, their analysis can be complex due to variability in plant chemistry, requiring expertise in both toxicology and botany.

Zeolites, Trace Minerals, and Silicas in Forensic Applications

Zeolites, trace minerals, and silica are increasingly used in forensic investigations to enhance analysis and evidence interpretation (Grela et al.). Zeolites, with their microporous structure, are effective in extracting and concentrating chemical compounds such as drugs and explosive residues, improving detection through techniques like HS-SPME and GC-MS (Wang et al.). Trace minerals, in-

cluding strontium and lead isotopes, provide insight into geographic origin, environmental exposure, and movement, making them valuable in cases involving unidentified remains, missing persons, and environmental forensics. However, careful handling and interpretation are required to avoid contamination and misclassification. Silica plays a key role in both gunshot residue (GSR) analysis and forensic geology. Its ability to capture fine particles aids in collecting GSR, which is analyzed using SEM-EDS to link individuals to firearm use. In forensic geology, silica and soil evidence can connect individuals or objects to specific locations, supporting investigations such as environmental crimes and hit-and-run cases. Overall, these materials enhance forensic sensitivity, accuracy, and the ability to reconstruct events when used alongside traditional methods.

The Influence of Sunlight in Decomposition Processes

Sunlight is an important environmental factor influencing decomposition and forensic analysis. It affects decomposition rates by increasing temperature, accelerating microbial activity, and promoting tissue breakdown. Sunlight also contributes to desiccation, which can lead to mummification and alter decomposition patterns. In addition, sunlight impacts insect activity, attracting species such as blow flies and accelerating colonization key factors in estimating postmortem interval (PMI). It also influences microbial communities and chemical processes like photodegradation, which can alter decomposition products and forensic evidence. Understanding sunlight's role helps forensic experts improve PMI estimates and interpret outdoor death scenes more accurately. However, factors such as climate, weather, and seasonal variation must also be considered to ensure reliable conclusions.

Traditional vs. Non-Traditional Approaches: Comparative Analysis

Forensic medicine relies on both traditional and non-traditional approaches to investigate deaths and criminal cases. Traditional methods include autopsies, fingerprint analysis, and ballistics, while non-traditional approaches such as vitamins, herbal compounds, zeolites, and environmental factors like sunlight expand investigative capabilities (Grela et al.).

Traditional Approaches

Postmortem examinations (autopsies) remain central, involving external and internal analysis to determine cause and manner of death. They provide critical evidence in criminal investigations and public health insights but are time-consuming and depend on well-preserved remains. Fingerprint analysis is a reliable method for identifying individuals due to the uniqueness of friction ridge patterns. It is widely used to link suspects to crime scenes, though results depend on print quality and examiner accuracy. Ballistics analysis examines bullets and firearms to connect weapons to crimes. By analyzing markings on bullets and cartridge cases, investigators can link firearms to specific incidents. However, it requires specialized tools and may be limited by evidence quality. Overall, traditional methods provide reliable and well-established frameworks, while non-traditional approaches offer innovative tools that enhance forensic investigations when used together.

Non-Traditional Approaches

Non-traditional methods complement traditional forensic techniques by providing additional insight into identity, environment, and cause of death. Vitamins can act as biomarkers for diet and lifestyle, while minerals help determine geographic origin and environmental exposure (De Giuseppe et al.). Herbal compounds aid in toxicology, and materials like zeolites and silica help detect environmental and chemical evidence. Sunlight also influences decomposition and improves postmortem interval (PMI) estimation. Overall, these approaches enhance forensic analysis and provide a more comprehensive understanding of complex cases.

Comparative Strengths and Weaknesses

Traditional forensic methods such as autopsies, fingerprint analysis, and ballistics are highly reliable and well-established, making them essential for determining cause of death and identifying individuals. However, they depend on well-preserved remains, known comparison data, and significant resources, which can limit their effectiveness in complex or degraded cases. Non-traditional approaches, including vitamin, mineral, and environmental analyses, offer valuable complementary insights. They can aid identification,

provide information on lifestyle or geographic origin, and help interpret environmental factors like decomposition. These methods are especially useful when traditional techniques are inconclusive. Despite their benefits, non-traditional methods often require specialized expertise and equipment and may have less established scientific validation, which can limit their acceptance in legal settings. Overall, combining both approaches provides the most comprehensive and effective forensic analysis.

The Complementary Role and Integration of Forensic Approaches

Traditional and non-traditional approaches in forensic medicine work best when used together. Traditional methods such as autopsies, DNA analysis, and fingerprinting provide reliable determination of cause of death and identification. However, they may be limited in complex cases involving decomposition, dismemberment, or unidentified remains. Non-traditional approaches, including vitamin, mineral, and environmental analyses, offer additional insights into identity, geographic origin, lifestyle, and environmental conditions. These methods help fill gaps when traditional techniques are inconclusive, particularly in challenging or degraded cases. Integrating both approaches creates a more comprehensive and accurate forensic process. Together, they improve identification, refine cause-of-death determination, and enhance investigations in scenarios such as mass disasters or advanced decomposition. This combined strategy allows forensic medicine to remain adaptable, effective, and better equipped to uncover the full circumstances surrounding death.

Environmental Insights, Flexibility, and Global Considerations

Non-traditional approaches provide valuable environmental insights in forensic medicine, helping determine postmortem interval (PMI), environmental exposure, and circumstances of death. Analyses of minerals, toxins, and ecological factors can reveal geographic origin and environmental conditions that traditional methods may overlook (Grela et al.). These approaches also enhance flexibility in complex cases, such as advanced decomposition or limited evidence, by detecting substances or patterns not visible through conventional methods. Integrating both traditional and non-traditional techniques allows forensic practitioners to adapt to diverse and challenging scenarios. Globally, this integrated approach improves cross-border investigations, supports identification in diverse populations, and strengthens international justice efforts. However, ethical and legal considerations such as consent, evidence admissibility, chain of custody, and data protection must be carefully maintained to ensure reliability and uphold individual rights.

Postmortem Changes and Findings in Drowning Cases

Drowning investigations rely on identifying key postmortem changes. One common sign is wrinkled skin ("washerwoman's fingers"), which develops after prolonged water immersion and helps estimate the postmortem interval (PMI). Decomposition rates in water vary based on temperature, depth, and microbial activity, influencing timelines and body condition. A major internal finding is emphysema aquosum, characterized by lung hyperinflation caused by water entering the airways. This may be accompanied by subpleural hemorrhages (Paltauf's spots) and varies between freshwater and saltwater drowning. These features are critical in determining cause of death. Pathological investigation combines traditional autopsy with non-traditional methods such as radiology and diatom analysis. Diatoms microscopic aquatic organisms found in tissues can confirm drowning when they match the surrounding water source. Despite some limitations, these combined approaches improve accuracy in diagnosing drowning and reconstructing events.

Alcohol: Metabolism, Effects, and Tolerance

Blood Alcohol Concentration (BAC) measures ethanol levels and is used in forensic medicine to assess intoxication in cases like DUI (Jones and Derrick). BAC correlates with impairment, though factors such as age, sex, and metabolism influence its effects. Alcohol is metabolized in the liver by enzymes like ADH and ALDH, and it acts as a central nervous system depressant, impairing judgment, coordination, and behavior while affecting multiple organ systems. Chronic alcohol use can lead to tolerance, where individuals require more alcohol to feel the same effects and may appear less impaired despite high BAC levels. This results from both increased metabolic activity and reduced neurological sensitivity, complicating forensic evaluations. Despite tolerance, high BAC remains dangerous and can cause serious health consequences.

Conclusion

Forensic medicine is a multidisciplinary field that plays a critical role in both criminal and civil justice systems. It encompasses a wide range of practices, including determining cause and manner of death, identifying human remains, evaluating injuries, and conducting toxicological analyses. Traditional methods such as autopsies, DNA profiling, fingerprint analysis, and ballistics remain the foundation of forensic investigations due to their reliability, accuracy, and legal acceptance. However, the growing integration of non-traditional approaches including the analysis of vitamins, minerals, herbal compounds, and environmental factors has significantly expanded the capabilities of forensic science. These methods provide valuable complementary insights, particularly in complex cases involving decomposition, environmental exposure, or unidentified remains. By offering information on lifestyle, geographic origin, and biochemical changes, non-traditional approaches help fill gaps when conventional methods are limited.

The combined use of traditional and non-traditional techniques allows for a more comprehensive and accurate understanding of forensic cases. This integrative approach enhances identification processes, refines cause-of-death determinations, and improves the reconstruction of events, especially in challenging scenarios such as mass disasters or advanced decomposition. As forensic medicine continues to evolve, ongoing research, standardization, and interdisciplinary collaboration will be essential to ensure the reliability and legal acceptance of emerging methods. Ultimately, the strength of forensic medicine lies in its ability to adapt, integrating innovation with established practices to support justice, protect individual rights, and contribute to public health on a global scale.

References

1. Ahmad Imtiaz., et al. "Zeolite imidazole framework entrapped quantum dots (QDs@ ZIF-8): encapsulation, properties, and applications". *Journal of the Taiwan Institute of Chemical Engineers* 149 (2023): 104993.
2. Ahmed Hussein Ali and Nagham Mahmood Aljamali. "Preparation, characterization, antibacterial study, toxicity study of new phenylene diamine-formazan derivatives". *Indian Journal of Forensic Medicine & Toxicology* 15.2 (2021): 3102-3112.
3. Akhgari Maryam, Noushin Amini-Shirazi and Fariba Sardari Iravani. "Forensic toxicology perspectives of methadone-associated deaths in Tehran, Iran, a 7-year overview". *Basic & clinical pharmacology & toxicology* 122.4 (2018): 436-441.
4. Amer Nehal Ahmed. "Histopathological Alteration in the Spleen of Male Albino Rats Exposed to Sodium Fluoride with the Protective Role of Resveratrol". *Zagazig Journal of Forensic Medicine* 20.2 (2022): 125-149.
5. Andresen-Streichert Hilke., et al. "Alcohol biomarkers in clinical and forensic contexts". *Deutsches Ärzteblatt International* 115.18 (2018): 309.
6. Ansari Anees A., et al. "Recent progress of fluorescent materials for fingermarks detection in forensic science and anti-counterfeiting". *Coordination Chemistry Reviews* 462 (2022): 214523.
7. Arica Enes., et al. "ICP-MS determination of lead levels in autopsy liver samples: An application in forensic medicine". *At Spectrosc* 39.2 (2018): 62-66.
8. Barik, Mayadhar. "Post Mortem CT (PMCT) in Forensic Medicine and Toxicity". *Journal of Forensic Chemistry and Toxicology* 5.1 (2019).
9. Baymakov SR., et al. "Our Experience in Treatment Acute Surgical Diseases of the Abdominal Cavity in Patients with Situs Inversus Viscerum (Transposition of Internal Organs)". *Indian Journal of Forensic Medicine & Toxicology* 14.4 (2020): 7753-7757.
10. Behl Akanksha, Amarnath Mishra and GP Sharma. "A Critical Scientific Review on Withania somnifera, Garcinia cambogia and Curcumin Supplements: Food Forensics Perspective". *Current Nutrition & Food Science* 18.1 (2022): 31-41.
11. Bierens Joost JLM., et al. "Physiology of drowning: a review". *Physiology* 31.2 (2016): 147-166.
12. Bohnert M. "Burns and scalds". *Forensic Pathology* (2016): 127.
13. Byard Roger W and Hamish Maxwell-Stewart. "Scurvy—characteristic features and forensic issues". *The American journal of forensic medicine and pathology* 40.1 (2019): 43-46.
14. Cappello Silvia., et al. "Elevated plasma vitamin B12 concentrations are independent predictors of in-hospital mortality in adult patients at nutritional risk". *Nutrients* 9.1 (2017): 1.

15. Carlier Jérémy., et al. "Screening approach by ultra-high performance liquid chromatography–tandem mass spectrometry for the blood quantification of thirty-four toxic principles of plant origin. Application to forensic toxicology". *Journal of Chromatography B* 975 (2015): 65-76.
16. Choudhary PALLAVI, A Seth and K Lata Verma. "Detection of adulterants and contaminants in black pepper, cumin, fennel, coriander and turmeric using GC-MS technique for forensic investigation". *Iranian Food Science & Technology Research Journal* 18.3 (2022).
17. Cordner Stephen and Morris Tidball-Binz. "Humanitarian forensic action—its origins and future". *Forensic Science International* 279 (2017): 65-71.
18. De Giuseppe Rachele., et al. "Development of a Short Questionnaire for the Screening for Vitamin D Deficiency in Italian Adults: The EVIDENCE-Q Project". *Nutrients* 14.9 (2022): 1772.
19. Fahmy Khaled. *In quest of justice: Islamic law and forensic medicine in modern Egypt*. Univ of California Press, 2023.
20. Ferrara Santo Davide., et al. "Back to the Future-Part 2. Postmortem assessment and evolutionary role of the bio-medicolegal sciences". *International journal of legal medicine* 131 (2017): 1085-1101.
21. Gafner Stefan., et al. "Botanical ingredient forensics: Detection of attempts to deceive commonly used analytical methods for authenticating herbal dietary and food ingredients and supplements". *Journal of Natural Products* 86.2 (2023): 460-472.
22. González Marina., et al. "Methodologies applied to fingerprint analysis". *Journal of Forensic Sciences* 65.4 (2020): 1040-1048.
23. Grela Agnieszka., et al. "A Review on the Application of Zeolites and Mesoporous Silica Materials in the Removal of Non-Steroidal Anti-Inflammatory Drugs and Antibiotics from Water". *Materials (Basel, Switzerland)* 14.17 (2021): 4994.
24. Huestis Marilyn A., et al. "Impact of novel psychoactive substances on clinical and forensic toxicology and global public health". *Clinical Chemistry* 63.10 (2017): 1564-1569.
25. Jain B. *Guide to Forensic Medicine & Toxicology*. B. Jain Publishers (2023).
26. Jones A Wayne and Derrick J Pounder. "5.2 Measuring Blood-Alcohol Concentration for Clinical and Forensic Purposes". *Drug abuse handbook* (2019): 327.
27. Jones Alan W. "Alcohol, its analysis in blood and breath for forensic purposes, impairment effects, and acute toxicity". *Wiley Interdisciplinary Reviews: Forensic Science* 1.6 (2019): e1353.
28. Kordrostami Roya., et al. "Forensic toxicology analysis of self-poisoning suicidal deaths in Tehran, Iran; trends between 2011-2015". *DARU Journal of Pharmaceutical Sciences* 25 (2017): 1-10.
29. Marella Gian Luca., et al. "Diagnosis of drowning, an everlasting challenge in forensic medicine: review of the literature and proposal of a diagnostic algorithm". *Acta Med* 35 (2019): 900-919.
30. Metushi Imir G, Robert L Fitzgerald and Iain M McIntyre. "Assessment and comparison of vitreous humor as an alternative matrix for forensic toxicology screening by GC–MS". *Journal of Analytical Toxicology* 40.4 (2016): 243-247.
31. Michael Amy R and Jennifer D Bengtson. "Chronic alcoholism and bone remodeling processes: Caveats and considerations for the forensic anthropologist". *Journal of forensic and legal medicine* 38 (2016): 87-92.
32. P Busardo Francesco and Alan W Jones. "GHB pharmacology and toxicology: acute intoxication, concentrations in blood and urine in forensic cases and treatment of the withdrawal syndrome". *Current neuropharmacology* 13.1 (2015): 47-70.
33. Pan Meiru., et al. "A retrospective analysis of data from forensic toxicology at the Academy of Forensic Science in 2017". *Forensic science international* 298 (2019): 39-47.
34. Prosono Marvin Thomas. "History of forensic psychiatry". *Principles and practice of forensic psychiatry*. CRC Press (2017): 45-62.
35. Rivers David B and Gregory A Dahlem. *The science of forensic entomology*. John Wiley & Sons (2022).
36. Rojek Sebastian., et al. "A new challenge in forensic toxicology exemplified by a case of murder under the influence of a synthetic cannabinoid-AM-2201". *Legal Medicine* 27 (2017): 25-31.
37. Shakeri Masihallah., et al. "Successful treatment of acute aluminum phosphide poisoning by aloe vera syrup: A case report". *International Journal of Medical Toxicology and Forensic Medicine* 11.2 (2021): e33016.
38. Sohail Anas Anas., et al. "The Effects of Caffeine and L-Theanine as a Cognitive Enhancer: A Systematic Review". *Cureus Journal*

of Medical Science (2021).

39. Stallman Robert Keig., et al. "From swimming skill to water competence: Towards a more inclusive drowning prevention future". *International Journal of Aquatic Research and Education* 10.2 (2017): 3.
40. Szeremeta Michal., et al. "Applications of metabolomics in forensic toxicology and forensic medicine". *International Journal of Molecular Sciences* 22.6 (2021): 3010.
41. Ubelaker Douglas H. "A history of forensic anthropology". *American Journal of Physical Anthropology* 165.4 (2018): 915-923.
42. Wang Bolun., et al. "Blue photoluminescent carbon nanodots prepared from zeolite as efficient sensors for picric acid detection". *Sensors and Actuators B: Chemical* 253 (2017): 911-917.
43. Wang Hui., et al. "Forensic appraisal of death due to acute alcohol poisoning: three case reports and a literature review". *Forensic sciences research* 5.4 (2020): 341-347.