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Mini Review

Forensic Mycology: An Emerging Tool for Criminal Investigations in Iran

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Abstract

Forensic mycology utilizes fungal identification to enhance criminal investigations, emerging as a powerful tool in forensic science. Fungi, ubiquitous in diverse environments, provide critical evidence for estimating post-mortem intervals (PMIs), locating buried remains, identifying trace evidence, and determining causes of death, including poisonings and biological warfare. Fungal spores, functioning as environmental signatures, link suspects to crime scenes. Although well-established in developed nations, forensic mycology remains largely unexplored in Iran. This mini-review explores forensic mycology's applications and feasibility for implementation within Iran's judicial system, and proposes strategies for adoption, including specialized training, infrastructure development, and policy integration. By leveraging Iran's exceptional fungal biodiversity, these strategies aim to strengthen criminal investigations and position Iran as a regional leader in forensic science innovation.

Background

Mycology, the scientific study of fungi, encompasses various fungal phyla, including Ascomycota, Basidiomycota, and Chytridiomycota. Mycologists also investigate non-fungal organisms such as Oomycota and Myxomycota [1]. Fungi are heterotrophic organisms with chitin-containing cell walls and comprise diverse forms, including molds, mushrooms, yeasts, lichens, mildews, rusts, and smuts. These organisms interact with their environment and other species as commensals, mutualists, pathogens, or saprotrophs. A defining characteristic is their production of spores, which disperse actively (e.g., in Pilobolus) or passively [1]. Forensic mycology integrates mycological expertise with criminology to support criminal investigations [2]. Fungal spores, often microscopic yet taxonomically distinct, are frequently detected on victims' clothing, hair, or skin, serving as valuable trace evidence [2]. Moreover, fungi colonize a wide range of substrates, such as soil, stone, wood, textiles, plastics, and rubber, making them versatile forensic markers [3,4]. Well-established in developed nations, this discipline has been integrated into investigative practices for decades.

Introduction

Despite its global potential and successful application elsewhere, forensic mycology remains largely underutilized within Iran's judicial and forensic systems. Iran has exceptional fungal biodiversity. It also has a pressing need to modernize its forensic infrastructure. to address complex crimes, including terrorism and environmental crimes, making its adoption in Iran crucial. This mini-review aims to investigate the applications of forensic mycology in criminal investigations, assess the feasibility of its integration into Iran's judicial framework, and propose actionable strategies for institutional implementation. By advocating for policy reforms, strengthening Research and Development (R&D), and establishing specialized forensic mycology units, this review seeks to position Iran as a regional leader in forensic science innovation.

Applications of forensic mycology

Post-mortem interval estimation

Fungal colonization, influenced by environmental factors such as temperature and humidity, provides temporal insights

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for estimating the PMI through species-specific growth rates and colonization durations [2,5,6].

Linking suspects to crime scenes or victims

Fungal spores, unique to specific habitats, serve as environmental fingerprints. Rare fungi or distinct fungal assemblages on a suspect's clothing or body can link them to specific locations or individuals [7].

Locating clandestine graves

Certain chemoecological fungal groups thrive in decomposition-rich environments associated with buried remains, serving as above-ground grave markers [4,8,9].

Identifying toxic substances and biological agents

Some fungi produce toxic metabolites, the detection of which can indicate poisonings, hallucinations, or use in biological warfare.

Determining body relocation and crime scene characterization

Spore profile analysis can determine body relocation or scene characteristics [2,5]. Pioneering studies, including van de Voorde and van Dijck [6], established the utility of fungi in PMI estimation. Over the past half-century, nations such as the United States and the United Kingdom have integrated forensic mycology into investigations, underscoring its reliability [2].

Forensic mycology in practice

Criminal investigations often begin when the cause of death is unknown, prompting forensic experts to employ interdisciplinary techniques. These techniques are drawn from disciplines including archaeology, botany, entomology, genetics, geology, mycology, palynology, soil microbiology, and taphonomy to assess changes in cadavers and surrounding soil for PMI estimation. Forensic mycology, an emerging field, merges mycology with criminology, encompassing sub-disciplines including morphology, molecular biology, taxonomy, and systematics. Forensic mycologists, typically trained in mycology or biology, analyze fungal spores to connect evidence to crimes, in contrast to forensic anthropologists, who focus on human remains. In developed countries, these professionals serve in federal agencies, academic institutions, or as consultants for forensic laboratories, although specialized training programs are scarce. The earliest application of mycology to crime detection dates back over five decades, yet its use remains largely confined to developed nations [2-5,7,9].

Potential in Iran

Iran's diverse ecosystems and climates foster exceptional fungal biodiversity, making it an optimal setting for forensic mycology applications [2]. For example, numerous fungal species have been documented in the Caspian Hyrcanian forests and the Zagros Mountains, including unique Ascomycota and Basidiomycota taxa that could serve as forensic markers [10-12]. Institutions such as the Iranian Research Institute of Plant Protection and the Iranian Research Organization for Science and Technology (IROST) in Tehran conduct robust mycological research, with studies on fungal taxonomy and ecology that could be adapted for forensic purposes. To date, no forensic mycology cases have been officially published in Iran, collaborations between centers of higher education and international mycological societies provide a robust foundation for developing forensic applications. Regionally, Turkey has advanced forensic palynology, leveraging pollen and spore analysis in criminal investigations, e.g., homicide cases [7], but its fungal biodiversity is less extensive than Iran's. Pakistan, while progressing in forensic entomology, lacks dedicated forensic mycology programs, highlighting Iran's opportunity to lead in this field. Despite a strong scientific infrastructure, awareness among Iran's judicial and law enforcement agencies remains low, and the judicial system has yet to adopt forensic mycology. The increasing complexity of crimes, including terrorism, drug trafficking, and environmental violations, necessitates advanced forensic tools. Forensic mycology can significantly enhance PMI estimation, trace evidence analysis, and counter-terrorism efforts, as demonstrated globally [2,3].

Challenges to implementation in Iran and proposed solutions

Scarcity of trained personnel and specialized facilities

A major hurdle is the scarcity of forensic mycologists and dedicated facilities. This can be addressed by outsourcing services to universities with mycology expertise and investing in laboratory infrastructure and training.

Low awareness among authorities

Limited awareness of forensic mycology's value among security, judicial, and law enforcement decision-makers hinders adoption. Targeted awareness campaigns, workshops, and presentations can effectively demonstrate the utility and reliability of mycological evidence.

Need for local validation studies

The applicability of forensic mycology principles requires validation in Iran's unique ecosystems. Local field studies, such as those identifying fungi as grave markers in diverse climates and soil types, are essential to build databases and refine techniques.

Ensuring reliability of estimates

a) Fungal Identification: The reliability of PMI estimates and other mycological conclusions depends on precise fungal identification, proper evidence collection, and adherence to body storage protocols.

b) Environmental Data Handling: Accurate environmental data, such as temperature and humidity at crime scenes, is crucial for ensuring the validity of forensic mycological assessments.

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Practical implementation strategies for Iran

Developing human capital

Specialized training programs, including short courses, workshops, and modules within forensic science degrees, should be established. Forensic mycology should be integrated into university curricula across biology, microbiology, forensic science, and law to foster foundational knowledge. Postgraduate research and qualifications in forensic mycology should be actively encouraged. This could be incentivized through scholarships, joint research programs, or international partnerships.

Establishing infrastructure and services

Formal partnerships between law enforcement, judicial bodies, and university microbiology or mycology departments should be developed to provide analytical services, share equipment, and conduct joint research under stringent legal and ethical oversight. Existing laboratories should be equipped with advanced tools, including high-quality microscopes, DNA sequencing technologies, and culture collections. In the long term, dedicated forensic mycology units should be established within national or regional forensic laboratories.

Policy and legal integration

Forensic mycology should be integrated into national forensic policy frameworks, with clear standards for its use. Regular workshops (e.g., bi-annual) should be held in collaboration with legal training centers. Standardized Operating Procedures (SOPs) for the collection, preservation, transportation, and analysis of fungal evidence are essential to ensure quality and admissibility in court.

Fostering Research and Development (R&D)

Funding could be sought from national science agencies or international grants to create comprehensive databases of forensically relevant fungi across Iran's diverse ecoregions. This is critical for accurate geographical sourcing of evidence. Interdisciplinary research projects involving mycologists, forensic scientists, soil scientists, and ecologists should be supported. Collaborations with international forensic mycology experts and institutions should be sustained and expanded to share knowledge, best practices, and technological advancements.

Conclusion

Forensic mycology offers a valuable, underutilized tool for Iran's judicial system. Iran can leverage its fungal biodiversity. Strategic investments in training and infrastructure are essential. Iran can bolster criminal investigations, particularly in PMI estimation, trace evidence analysis, and counter-terrorism. Strategic investments in training, laboratory infrastructure, and awareness campaigns among judicial and law enforcement agencies are essential for adoption. By embedding forensic mycology within national forensic policies, the country can strengthen its forensic capabilities. Additionally, promoting academic R&D will further advance scientific knowledge in this field, and establishing regional leadership, Iran can address its forensic challenges and contribute to global advancements in forensic science. As criminal methodologies evolve, adopting innovative disciplines such as forensic mycology will position Iran as a leader in forensic science.

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