

Pollen grains and their evidentiary value in criminal investigations.

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Abstract

This research addressed the scope of using palynology in criminal evidence, considering it an auxiliary science capable of providing accurate material evidence that could link the perpetrator to the crime scene. The importance of the study lies in clarifying the effectiveness of this science and highlighting the obstacles that hinder its utilization by criminal authorities, despite its success in several cases. The study's problem was the limited use of palynology in criminal investigations worldwide and the multiple challenges that reduced its effectiveness. This prompted the researcher to pose two main questions regarding the importance of science and the obstacles facing its application.

Moreover, the study adopted two approaches: the descriptive method to analyze scientific concepts and the case study method to present real-life examples of crimes in which palynology had been employed. The results showed that this science had proven successful in important criminal cases, but it faced challenges related to sample contamination, scarcity of experts, lack of equipment, and absence of standardized criteria.

The study recommended creating pollen databases, developing microscopic analysis techniques, training security personnel for crime investigation, establishing standardized protocols, and carefully collecting samples to ensure the reliability of results and their acceptance within the criminal justice system.

Keywords: Forensic Pollen Science, Crime Detection, Criminal Investigation, Criminal Evidence, Theoretical and Practical Training of Forensic Pollen Experts, Crime Scene.

حبوب اللقاح وحجيتها في الإثبات الجنائي

الملخص

تناولت هذه الدراسة دور علم حبوب اللقاح الجنائي في التحقيقات الجنائية، بوصفه أحد العلوم الجنائية المساندة القادرة على تقديم أدلة مادية موثوقة تساهم في ربط المشتبه به بمسرح الجريمة. وتنبع أهمية الدراسة من إبراز القيمة العلمية لهذا التخصص، وبيان فاعليته في دعم إجراءات التحقيق الجنائي، إلى جانب تسليط الضوء على التحديات التي ما تزال تحد من اعتماده على نطاق واسع من قبل سلطات العدالة الجنائية، رغم نجاحه في العديد من القضايا الجنائية.

وتتمثل مشكلة الدراسة في محدودية توظيف علم حبوب اللقاح الجنائي في التحقيقات الجنائية على المستوى العالمي، وما يواجهه من معوقات تحد من فاعليته وتطبيقه العملي. وانطلاقاً من ذلك، سعت الدراسة إلى الإجابة عن سؤالين رئيسيين يتعلقان بأهمية هذا العلم بوصفه وسيلة للإثبات الجنائي، والعوائق التي تحول دون الاستفادة المثلى منه في مجال التحقيقات الجنائية.

ولتحقيق أهداف الدراسة، اعتمدت الدراسة على المنهج الوصفي التحليلي لتحليل المفاهيم العلمية والأسس النظرية المرتبطة بعلم حبوب اللقاح الجنائي، إلى جانب منهج دراسة الحالة من خلال استعراض وتحليل عدد من القضايا الجنائية التي أسهم فيها هذا العلم في الكشف عن ملابسات الجريمة.

وأظهرت نتائج الدراسة أن علم حبوب اللقاح الجنائي يمتلك قدرة كبيرة على دعم التحقيقات الجنائية، وقد أثبتت فاعليته في عدد من القضايا المهمة. إلا أن تطبيقه لا يزال يواجه عدة تحديات، من أبرزها تلوث العينات، ونقص الخبرات المتخصصة، وقصور الإمكانيات والتجهيزات المخبرية، إضافة إلى غياب المعايير والبروتوكولات الموحدة لتحليل الأدلة المستمدة من حبوب اللقاح.

وفي ضوء هذه النتائج، أوصت الدراسة بإنشاء قواعد بيانات شاملة لحبوب اللقاح، وتطوير تقنيات التحليل المجهرية، وتعزيز برامج التدريب المتخصص للعاملين في الأدلة الجنائية ومحققى مسرح الجريمة، ووضع بروتوكولات معيارية موحدة لجمع وتحليل العينات، مع الالتزام بإجراءات دقيقة في جمع الأدلة؛ بما يضمن موثوقية النتائج ويعزز قبولها أمام جهات العدالة الجنائية.

الكلمات المفتاحية: علم حبوب اللقاح الجنائي، كشف الجرائم، التحقيق الجنائي، الأدلة الجنائية، التأهيل العلمي والتدريب العملي لخبراء حبوب اللقاح الجنائية، مسرح الجريمة.

Introduction

Solving crimes and connecting them to their perpetrators is often challenging in many criminal cases. Numerous offenses committed in the 20th century remained unsolved by criminal investigations. A factor contributing to this failure was the lack of adequate evidence to complete the investigations, especially since perpetrators have become increasingly adept at avoiding leaving physical traces (such as blood, hair, broken objects, or fingerprints) at the crime scene.

In light of this challenge, forensic experts, during the 20th century, had to adopt interdisciplinary methodologies, one of which involved palynology (the study of pollen grains). This approach arose from their recognition of the distinctive characteristics of pollen grains, which can provide a crucial forensic tool in solving some crimes, when all other evidence is absent or when the available evidence is secondary and insufficient on its own to identify the suspect or the victims.

Indeed, by extracting and analyzing pollen samples, palynologists can determine the time and possible location where these pollen grains were found. This could include samples collected from the crime scene, the suspect's body, or the victim's body or clothing. Such analyses can provide physical evidence that assists investigators in solving complex and mysterious criminal cases.

Therefore, incorporating palynology into forensic science represents a significant step forward in crime detection, as it offers a reliable method for presenting forensic evidence. The accuracy and objectivity of analyzing pollen samples can contribute to criminal investigations. Combined with traditional investigative methods. This interdisciplinary approach can lead to more effective crime solving and provide additional support in criminal proof.

Study Importance

The importance of studying pollen science lies in overcoming the challenges of optimally utilizing this science in forensic evidence. This is achieved by taking the necessary precautions to preserve pollen samples from contamination by accurately collecting and securely storing them.

This preparation sets the stage for their microscopic analysis using modern and advanced scientific methods, which enhances the accuracy of the results derived from the samples. It also ensures adherence to ethical values, such as neutrality in selecting the pollen samples and objectivity in interpreting the results. This provides reliable evidence to the investigating authority to prove or disprove the connection between the suspect and the crime.

Study Problem

Despite the significant benefits that pollen science offers in forensic evidence, this field has not been sufficiently utilized in many countries. This is due to challenges or obstacles that hinder its use. To overcome these challenges and find solutions, it was necessary to raise the following two questions:

1. What is the importance of resorting to pollen science in uncovering crimes?
2. What are the challenges preventing criminal investigation authorities in various countries from utilizing pollen science effectively?

Methodology

To find solutions to the problem presented in this study, it was necessary to adopt two interconnected methodologies that complement each other: the descriptive approach, which involves presenting the research topic through its scientific literature, and the case study analysis approach, which presents examples of crimes related to the study topic.

Literature Review

- A study by Heather Miller Coyle, Cheng-Lung Lee, Wen-Yu Lin, Henry C. Lee, and Timothy M. Palmbach (2025) titled "Using plant evidence to aid in forensic death investigation," which discussed the critical role of precise collection, documentation, and preservation for subsequent scientific analysis in evaluating plant evidence to determine the manner or time of death. Plant evidence can be useful in determining whether the death was accidental, a suicide, or a homicide, as well as identifying when the body may have been buried during the year, and locating missing bodies.

- A study by Ahmed El-Sayed Abdel-Razaq Bator (2022) titled "Forensic Pollen Science and Its Role in Achieving Criminal Justice," which explored the importance of using forensic pollen in criminal evidence and how it can be employed to resolve crime mysteries and identify perpetrators. The study concluded that the pollen technique is effective in extracting forensic evidence to identify criminals, particularly in countries that have employed this technique in criminal investigations, such as New Zealand and the United States.

- A study by Ibrahim Bin Sadiq Al-Jundi and Mohammed Ali Al-Saad (2004) titled "Applications of Pollen Examination Technology in Crime Detection," which defined forensic pollen analysis. The study highlighted the role of pollen examination in guiding the geographic source of pollen and linking it to the crime scene where it was found.

Despite the long-known nature of this technique, its use was rare, and the study recommended conducting extensive research to attract police attention and activate its role in criminal cases.

Study Plan

The researchers divided the study into two sections. The first section addresses the role of pollen science in criminal investigations, and the second discusses the challenges faced by pollen science experts in optimally utilizing pollen science for forensic evidence.

Section One: The Role of Pollen Science in Crime Detection

This chapter has been divided into two sections to understand how pollen science plays a role in offense detection.⁴⁵²⁴ The first section examines the characteristics of pollen and its distinctive

⁴⁵²⁴ Forensic pollen science is used to obtain accurate evidence from suspects, victims, or any items suspected to be connected to the crime scene. Additionally, it is used to determine the geographical location of the samples. The foundation of forensic pollen science lies in the analysis of pollen grains. Although it is not widely used, it has gained

attributes that make it a valuable tool in forensic investigations for crime detection. The second section reviews several cases where pollen science has been employed to solve crimes, including murder and drug trafficking.

Subsection One: Characteristics of Pollen

There are over half a million different plant species worldwide. Each plant has unique pollen that distinguishes it from other species. Additionally, certain regions contain pollen specific to that area and found nowhere else. Pollen is ubiquitous in the environment, although it remains imperceptible to the unaided eye.

On average, each cubic meter of outdoor air in a city contains about one hundred thousand pollen grains, while each cubic meter in indoor spaces contains around five thousand pollen grains. When pollen dust comes into contact with our bodies, clothing, or hair, it remains attached, though its quantity may decrease with each wash cycle; however, it never completely disappears.

Due to pollen's unique characteristics, pollen experts, particularly in New Zealand and the United States, have relied on the "Exchange Principle" proposed by scientist Edmond Locard. This principle asserts that "whenever two bodies come into contact, each will leave a trace of its material on the other."

The accuracy of the results obtained from a pollen sample, so that it can be used as forensic evidence, depends on the nature of the pollen produced by the plant and its mode of dispersal. These are key factors that help the pollen expert link a specific mixture of pollen to a particular geographic location or event. For instance, if pollen extracted from dust or dirt found on the suspect's clothing is identical to the pollen found at a crime scene, this indicates a potential connection.

However, if the pollen found at the crime scene is in abnormal quantities that are not expected for that location, this may indicate that something went wrong, perhaps an attempt at misleading the investigation by the perpetrator. For example, if a pollen expert determines that the sample of dirt found on the suspect's belongings, such as their car or shoes, supposedly originates from a location the suspect claims, but after examination and comparison, it is found that the pollen from

recognition for its ability to provide information about the pollen and dust found at the crime scene, or on clothing or other items of interest, primarily to solve civil and criminal cases. Forensic pollen science can be traced back to Austria more than fifty years ago, and many other countries have recently started to utilize it. However, it is not widely applied in countries such as the United States. It can be inferred that many cases, particularly murders, thefts, and some related to drugs, have been solved with the help of forensic pollen science. Currently, the United Kingdom leads in the use of forensic pollen science, followed by New Zealand. Vaishnavi, Mohith S Yadav, "CURRENT TRENDS IN FORENSIC PALYNOLOGY," International Journal of Engineering Applied Sciences and Technology, 6 (12), p. 255.

https://www.researchgate.net/publication/374847607_CURRENT_TRENDS_IN_FORENSIC_PALYNOLOGY_A_REVIEW_STUDY

4525 Pollen Helps Solve Crime Mysteries, Al-Rai Jordanian Newspaper, Published on Saturday, 19-12-2009, at 12:00 PM. <https://alrai.com/article/368301>

Vaughn Bryant and Gretchen Jones, Pollen and Solving Crime, December 21, 2009, p. 2. <https://askabiologist.asu.edu/pollen-and-solving-crime>

4526 Ibrahim Bin Sadiq Al-Jundi, Mohammed Ali Al-Saad, Applications of Pollen Examination Technology in Crime Detection, Security Research Journal - King Fahd Security College / Research and Studies Center, Riyadh, Volume (12), Issue (26), 2004, p. 100 and beyond.

4527 Zoe Schlanger, Pollen Helps Scientists Trace Crime Traces, Al-Sharq Al-Awsat Newspaper, Published on 14/7/2019, at 11:56 PM.

4528 Nawar Mustafa Zuhair, Crime Scene Examination and Its Role in Revealing the Truth, Master's Thesis, Faculty of Law and Political Science, Abdelhamid Mehri University, Mostaganem, Algeria, 2022, p. 40.

Ibrahim Bin Sadiq Al-Jundi & Colleague, Op. Cit., p. 99.

4529 Ibrahim Bin Sadiq Al-Jundi & Mohammed Ali Al-Saad, Op. Cit., p. 106.

that location differs from what is on the suspect's property, the alleged source of the sample is ruled out. This casts doubt on the suspect's claim and invalidates their assertion.

Pollen varies in terms of its spread and its transfer from one plant to another through different methods. These methods include:

First: Cross-Pollination Plants: Pollen from cross-pollinating plants spreads either through insects, air, or water. This can be further explained as follows:

1. Spread by Insects: Pollen spread by insects is characterized by having a strong outer wall, making it less likely to break apart or degrade during the transfer process from one location to another. As a result, it remains intact for a long period, even when found in soil⁴⁵³⁰. Furthermore, the production of such pollen is typically in small quantities; it is unusual for this pollen to be found clustered with pollen from other regions.

Thus, the presence of pollen from a specific type of plant that is cross-pollinated by insects in a sample related to a crime, such as a sample taken from a suspect, indicates that the pollen likely belongs to that sample and is not the result of atmospheric contamination. This allows for a connection to be made between the suspect and the crime scene.

For example, when pollen from an insect-pollinated plant is found on a suspect's hair or clothing, it serves as evidence that the suspect was present at the location where the victim's body was discovered. If a matching sample of pollen is also found at the crime scene, it strongly suggests the suspect's involvement, unless they can provide evidence of other reasons for their presence at the location of the body, such as proving that the pollen on their hair or clothing resulted from atmospheric factors.⁴⁵³¹

2. Spread by Air: Plants that rely on air for pollination produce large quantities of small, lightweight pollen grains, such as those from marijuana, juniper, and birch trees. This enables them to spread as dust in the air, which then settles on distant objects away from the plant producing the pollen. In contrast, heavier pollen grains, like those from corn or rice plants, settle over a limited area and, therefore, do not travel over long distances.

This is an important consideration in crime detection. The presence of heavy pollen grains indicates that the sample was collected from a location near the fields where the plant producing the pollen grows. Therefore, this can help identify the origin of the pollen and establish a connection between the suspect and the crime scene. For instance, if heavy pollen grains are found on the suspect's clothing or on drugs they possess, it suggests that the suspect was in an environment close to where this particular plant, which produces heavy pollen, grows.⁴⁵³²

3. Spread by Water: Pollen from plants submerged under water has little to no value in crime detection. This is because such pollen does not settle in the soil, and it quickly decays once removed from the water.

Second: Self-Pollinating Plants: Some plants are capable of self-pollination; therefore, the pollen of these plants does not disperse elsewhere. Consequently, this pollen has little to no value in the context of criminal investigations.⁴⁵³³

Subsection Two: Case Study of Certain Crimes

The science of pollen has provided crucial evidence in many important criminal cases, facilitating the work of investigators in establishing connections between crime scenes, suspects, and victims. This

4530 Eusebio Cano Carmona, Ana Cano Ortiz, Riocardo Quinto Canas and Carmelo Maria Musarella, Vegetation Index and Dynamics, 2022, (<https://www.intechopen.com/chapters/77048#>).

4531 Ibrahim Bin Sadiq Al-Jundi & Colleague, Op. Cit., pp. 107-106.

4532 Vaughn Bryant, Reference previously mentioned, p4.

4533 Ibrahim bin Sadiq Al-Jundi and Muhammad Ali Al-Saad, Previous Reference, pp. 107-108.

is particularly significant in cases where traditional evidence is lacking, such as in murder and drug trafficking crimes, as illustrated below:

First: In Murder Cases

Pollen experts in a government laboratory in Texas determined that the pollen collected from the clothing of the girl "Baby Doe" came from trees native to the Boston area. This indicated that the child, believed to be approximately four years old, lived in the Boston area. The girl was found in a trash bag with a blanket printed with a zebra design, wearing patterned tight pants, near the coast of Deer Island, a peninsula connected to the Winthrop neighborhood in Boston by a bridge. Pollen experts analyzed the pollen found on the girl's pants and blanket and concluded that the pollen came from trees and plants prevalent throughout Boston.

The autopsy performed by the state medical examiner did not immediately determine the cause of death. However, forensic tests revealed that the girl might have come from the New England area. Pollen samples from her blanket indicated that she likely spent some time in the Boston area before her death. Investigators believed she died somewhere in the region, not far from it. Michael Patrick McCarthy, the boyfriend of the girl's mother, Rachel Bond, was arrested and charged with murder. Bond herself was charged with complicity in the murder.⁴⁵³⁴

In Another Murder Case

In 2006, pollen expert Von Bryant used this science to solve a 27-year-old murder mystery by identifying a teenage girl found murdered in a cornfield in western New York in 1979. Bryant was able to determine that the Australian pine pollen found in the girl's jacket pocket and pants came exclusively from Florida or Arizona, with Florida being the more likely source. Bryant, the director of the Pollen Science Laboratory at Texas A&M University, stated that it would be impossible for the pollen to have reached that area of New York through air currents.

Bryant further analyzed around 40 other types of pollen found on the girl, which suggested that she had lived in or at least traveled through coastal areas in Southern California, such as San Diego. The police believed the girl, who was thought to be around 15 years old, was shot in the forehead on a rural road in Caledonia, New York, on November 8, 1979. She was then transported to the field, where she was shot again in the back. Bryant conducted interviews with two individuals who confessed to their involvement in the crime.⁴⁵³⁵

Second: In Drug Trafficking Crime

One of the important applications of pollen science is its ability to identify the source of drugs in several incidents. For example, after analyzing a sample of pollen found in cocaine, it was determined that some of the pollen came from tropical plants that typically grow in South America, particularly in areas of Bolivia and Colombia. A second group of pollen found in the cocaine came from sub-mountainous coniferous trees, including Canadian hemlock and jack pine. These two types of conifers do not usually grow in the same region; rather, they are found in limited areas of Eastern Canada and the Northeastern United States.

Therefore, the presence of pollen from both types of conifers in the same sample indicated that the cocaine was smuggled from South America to the United States. Once it arrived in New York City, it was exposed to airborne pollen before being packed with herbs and plants such as birch and

4534 Tasneem Nashrulla, Adolfo Flores, Authorities ID Body Of "Baby Doe," Little Girl Found Dead In Boston, BuzzFeed News, Posted on September 18, 2015 at 7:59 pm.

4535 Ben Dobbin, Murder investigators count on pollen to help solve 1979 case, Nation & World, published October 4, 2006, at 12:00 am

<https://www.seattletimes.com/nation-world/murder-investigators-count-on-pollen-to-help-solve-1979-case/>

goosefoot, which commonly grow in New York City. This explains the presence of two types of pine pollen in the same sample of cocaine.⁴⁵³⁶

Section Two: Challenges Faced by Pollen Experts in Obtaining Forensic Evidence from Pollen

Despite the significant potential that pollen science offers in criminal investigations, as it is an effective tool in determining locations related to crimes due to the distinctive characteristics of different types of pollen, such as variations in size and methods of dispersal, which enable pollen experts to establish effective links between suspects and crime scenes, some challenges hinder the optimal use of pollen science in providing decisive evidence to either prove or disprove a crime. These challenges can be divided into two main categories: one related to the preparation and quantity of the pollen sample, and the other related to the available material and human resources for examining the pollen.

Subsection One: Challenges Related to Pollen Sample Preparation

The process of extracting pollen from samples associated with a crime faces several challenges, the most prominent of which are contamination of the pollen sample with other pollen types (the first issue) and another related to the quantity of the available sample for examination (the second issue).

The First Issue: Contamination of the Sample with Other Pollen

Pollen samples may become contaminated with other pollen types during collection and improper storage, which could lead to incorrect conclusions during analysis by a pollen expert.⁴⁵³⁷ Such contamination would render the sample useless as evidence in a criminal investigation. However, this issue can be addressed by taking the necessary precautions to ensure the accuracy in collecting and preserving the samples. This reduces or eliminates the likelihood of contamination, making the results of the analysis more reliable for use in criminal investigations.

It is expected that pollen experts have sufficient experience to extract pollen in a scientifically sound manner that ensures the sample is not contaminated by other types of pollen. This can be achieved by confirming that the sample collection tools are free from airborne contaminants, dust, or any other pollen.

Additionally, the laboratories' ability to provide reliable conclusions based on scientific interpretation depends largely on how samples are collected and preserved. It is essential not to store more than one sample in a single container and to securely seal the sample using appropriate methods. By following these procedures, the pollen expert can confirm to the investigating authorities that the samples have not been contaminated, whether intentionally by the suspect or accidentally due to negligence by the expert. Thus, the pollen sample results can serve as legitimate evidence to either prove or disprove the charges against the suspect.⁴⁵³⁸

The Second Issue: The Quantity of the Available Pollen Sample for Examination

To conduct the necessary examination, a pollen expert must collect sufficient quantities of pollen samples from the suspect, the victim, or the crime scene⁴⁵³⁹. A sample that is too large may be

4536 Vaughn Bryant and Gretchen Jones, Reference previously mentioned .Karl Ritz, Lorna Dawson, David Miller, "Criminal and Environmental Soil Forensics, Springer Netherlands, 2008.

4537 Ibrahim bin Sadiq Al-Jundi and Muhammad Ali Al-Saad, Previous Reference, p. 119.

4538 Saqer S. Alotaibi a, Samy M. Sayed b, Manal Alosaimi a, Raghad Alharthi a, Aseel Banjar a, Nosaiba Abdulqader a, Reem Alhamed a, Pollen molecular biology: Applications in the forensic palynology and prospects: A review, Saudi Journal of Biological Sciences, Volume 27, Issue 5, May 2020, P 1185-1190 .

4539 Ines Pickrahn, Gabriele Kreindl, Eva Müller, Bettina Dunkelmann, Waltraud Zahrer, Jan Cemper-Kiesslich, Franz Neuhuber, Contamination when collecting trace evidence—An issue more relevant than ever? Forensic Science International: Genetics Supplement Series

Volume 5, December 2015, P 603-604 .(<https://www.sciencedirect.com/science/article/abs/pii/S1875176815000050>).

prone to contamination with other types of pollen, while a sample that is too small may not provide enough pollen to perform the required analysis and comparison.⁴⁵⁴⁰

For example, when collecting a pollen sample from a drug substance, such as cocaine, the examination process requires a full kilogram of the drug to obtain a sufficient quantity of pollen that can be used to identify the source of the drug. Ideally, at least 200 pollen grains are required for the analysis.⁴⁵⁴¹ Additionally, if the sample is small and errors occur during the examination, such as breaking the centrifuge tube containing the sample solution or spilling the container with the solution, the expert may be unable to extract the pollen correctly, rendering it an invalid piece of forensic evidence in a criminal investigation.⁴⁵⁴²

Subsection Two: Challenges Related to Human and Material Resources in Pollen Examination

The diversity of pollen types and their variations across different regions, depending on their characteristics and the surrounding climatic conditions, requires laboratories with specialized equipment. However, such laboratories are not available in most countries. Even when they do exist, they are often not equipped to examine all types of pollen.⁴⁵⁴³ Moreover, this process demands a high level of expertise from the pollen expert in handling pollen samples.

Hence, the analysis of pollen requires the collection of samples with various characteristics and the use of databases to classify the pollen. This helps improve the scientific accuracy of the results, ensuring reliable identification of pollen types and allowing for comparisons between samples taken from the crime scene and the reference databases. One of the major challenges in making these comparisons is the lack of standardized criteria in most countries to evaluate the accuracy of sample results, which hinders the broader application of pollen science in criminal investigations.

Furthermore, interpreting the results of pollen sample analysis relies on scientific judgments that may vary from one expert to another, complicating the understanding of the findings.⁴⁵⁴⁴ Therefore, it is essential to establish clear standards and protocols that contribute to building a comprehensive database for analyzing different criminal contexts. Adhering to these standards is crucial to achieving scientifically reliable results that support conclusions drawn from pollen evidence.⁴⁵⁴⁵

Additionally, ensuring that pollen experts follow ethical standards characterized by neutrality and objectivity, avoiding biases arising from sample selection or the interpretation of results, is critical. Maintaining scientific openness in discussing data to establish causal relationships in pollen sample analysis enhances the effectiveness of the evidence provided to criminal investigation authorities in legal cases.⁴⁵⁴⁶

4540 Ahmed Sayed Abdel Razak Bator, Forensic Pollen Science and Its Role in Achieving Criminal Justice, published by the General Command of Sharjah Police, Police Research Center, Volume (31), Issue (123), 2022, p. 235.

4541 Zoe Schlanger, Previous Reference, p. 1.

4542 Ibrahim bin Sadiq Al-Jundi and Muhammad Ali Al-Saad, Previous Reference, p. 111.

4543 Vaughn M. Bryant, Pollen and Spore Evidence in Forensics, 2014, p1.

<https://onlinelibrary.wiley.com/doi/10.1002/9780470061589.fsa085.pub2> .(

4544 Du, Mingxiao, Analysis of Errors in Forensic Science ,Journal of Forensic Science and Medicine Jul-Sep 2017, 3(3): p 139-143 . (https://journals.lww.com/jfsm/fulltext/2017/03030/analysis_of_errors_in_forensic_science.6.aspx)

4545 Julia Gravendyck, Robert A. Fensome, Martin J. Head, Patrick S. Herendeen, James B. Riding, Julien B. Bachelier, Nicholas J. Turland.

Taxonomy and nomenclature in palaeopalynology: basic principles, current challenges and future perspectives . Palynology, Volume 45, 2021, p 717-743.

.)<https://www.tandfonline.com/doi/full/10.1080/01916122.2021.1918279>(

4546 Mark O. Ezegbogu, Identifying the scene of a crime through pollen analysis, Science & Justice, Volume 61, Issue 3, May 2021, P 205-213.

(<https://www.sciencedirect.com/science/article/abs/pii/S1355030621000010?via%3Dihub>).

Conclusion

At the end of this study, we provide a concluding statement highlighting some of the findings and recommendations, which may serve as the foundation for future studies in the field of criminal investigations. This is particularly relevant in today's fast-paced era of science and knowledge, where there is a shortage of reliable evidence to aid in the detection of crimes and the unraveling of their complexities.

First: Findings

1. The research efforts of pollen science experts in entering the field of forensic sciences over the past years have succeeded in providing decisive evidence in numerous significant criminal cases, supported by many case studies that demonstrate its effectiveness in unsolved crimes. These efforts have helped establish links between the crime scene, the suspects, and the victims, thereby aiding criminal investigators in solving crimes and attributing them to specific suspects, especially in cases lacking traditional evidence for criminal proof.

2. Despite the considerable potential that pollen science offers to criminal investigators in terms of information obtained from pollen analysis, which either supports or enhances the available evidence, this field remains largely unknown to investigative authorities in many countries. In other countries like New Zealand and the United States, the use of pollen science in criminal investigations is still limited. Researchers have pointed out that the reason for the limited use of this science in most countries is the existence of challenges that hinder the optimal utilization of pollen science in providing conclusive evidence for the establishment or refutation of crimes. These challenges are related to the preparation of pollen samples, as the extraction process may result in contamination with other types of pollen. The diverse ecological patterns of pollen and their varying characteristics from region to region complicate the accurate identification of pollen, which can obstruct the necessary examination due to the lack of laboratories equipped to minimize sample contamination. Even when such laboratories exist, they may not be suitable for examining all types of pollen. Additionally, the optical microscope, which is crucial for analysis, may not be available in these laboratories. Even if present, the scarcity of pollen experts and the limited expertise of most in identifying pollen characteristics pose further obstacles to the effective utilization of this science in criminal investigations.

3. In addition to the two previously mentioned obstacles, a third challenge relates to the analysis of pollen samples, which requires collecting samples with diverse characteristics using reference sets designed to classify the samples according to strict standards and protocols to ensure the quality of the results. One of the most prominent challenges is the lack of standardized criteria to assess the accuracy of the sample results. Furthermore, interpreting the data relies on scientific estimations that may vary significantly among experts, leading to inconsistency in methodologies. Another challenge involves the general acceptance of the reliability of pollen sample results by judicial authorities.

Second: Recommendations

1. The findings of this study highlight the significance of pollen science in the detection of crimes, underscoring the need for greater attention from pollen experts to explore this science more deeply, particularly in understanding the different ecological patterns of pollen and the climatic factors influencing them.

2. It is essential to take the necessary precautions and maintain precision in the collection and preservation of pollen samples to address the issue of contamination. Reducing or eliminating the

risk of contamination greatly enhances the reliability of sample analysis results for use in criminal investigations. This problem can be alleviated if pollen experts are assumed to have the necessary experience to scientifically extract pollen in a manner that ensures the sample is not contaminated with pollen from other sources. This can be achieved by ensuring that the tools and containers used for collecting pollen samples are free from contamination by other pollen types.

3. There is a need to develop microscopic analysis methods to increase the accuracy of results extracted from pollen samples, making it a powerful tool for criminal investigations. This requires the establishment of high technical standards for examination and advanced skills for pollen experts, particularly in fields that rely on techniques such as optical microscopes, which demand a high level of expertise. Furthermore, microscopic analysis necessitates the availability of specialized skills and strict scientific discipline.

4. The study recommends the creation of a comprehensive pollen database, which would enhance the scientific accuracy and reliability of pollen sample examination results. This would contribute to improving the precision of species identification and facilitate comparisons between samples taken from crime scenes and existing reference data. Such a database would provide critical information necessary for criminal investigations.

5. The optimal response to the challenges associated with the use of pollen science lies in investing in both theoretical and practical training to improve performance in forensic evidence. This training should cover the fundamental principles of plant biology and advanced methodologies for pollen analysis, such as extraction techniques, to ensure accuracy. This training should be complemented by a deep understanding of pollen characteristics, including size and mass, which influence the dynamics of pollen dispersion and its potential applications in the analysis of pollen test results.

6. There is a need to formulate standardized protocols to ensure trust and repeatability in pollen examination environments, which will support the reliability of results obtained from scientifically based tests. These protocols must consider ethical values in the research and analysis of pollen samples, avoiding biases related to sample selection or result interpretation while maintaining neutrality and objectivity. This approach will reinforce the credibility of the results derived from pollen samples, ensuring their acceptance by criminal investigative authorities.

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