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Role of Forensic Palynology in Crime Investigation

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ABSTRACT

Forensic palynology is an important tool for obtaining trace evidence from victims, suspects, items related with a crime scene, or for determining the location of a sample. This discipline has been used in court and have provided evidence for contact of objects and places, location of disposed human body remains and graves, estimating times of deposition of bodies, determine primary crime scene and secondary crime scene. Palynology involves the identification pollen, plant spores, and fungal spores It is important for its ability to provide information about pollen and spores trapped in clothing or other items of interest needed to help resolve criminal and civil cases, including instances of homicide, terrorism, bombings, forgery, theft, rape, arson, counterfeiting, manufacturing and distribution of illegal drugs, assault, cases of hit and run, poaching, and identity theft. The use of pollen in forensic applications comes from the discipline of pollen analysis, which began a century ago as a way to search for clues about past environmental changes. In this paper we are discuss about pollen grains which are help in the crime investigation by collecting from different types of trace evidence.

Key Words: - Pollen, Palynology, Forensic, crime, Investigation.

INTRODUCTION

Forensic palynology has been a law enforcement tool for over 50 years. Forensic palynology is the application of pollen and spores in solving legal issues, either civil or criminal. Pollen and spores can be obtained from an extremely wide range of items, including bodies. Pollen and spores provide clues as to the source of the items and the characteristics of the environments from which the material on them is sourced [1]. Pollen and spore production and dispersion are important considerations in the study of forensic palynology. First, if one knows what the expected production and dispersal patterns of spores and pollen are for the plants in a given region, then one will know what type of "pollen fingerprint" to expect in samples that come from that area [2]. Soil, dirt, and dust are common elements at almost every crime scene. As such they should be collected carefully because often these elements contain abundant pollen and spores. Samples of dirt collected from the clothing, skin, hair, shoes, or car of a victim might prove useful in linking the victim with the location where the crime occurred [3]. There are a number of suspected reasons for the underuse of this technique worldwide.Palynology is the study of organic-walled microfossils. Two of the most abundant of these microfossils are pollen andspores. Forensic palynology uses "trace" evidence in the form of tiny grains of pollen and spores in legal cases [4]. Perhaps the area that will be most significantly affected will be the forensic disciplines that rely on the expertise of highly experienced and qualified expert witnesses but where there is a lack of an extensive corpus of peer reviewed, experimental work to provide the foundations of the discipline in a form that will be recognised by a reliability test. Forensic palynology is known to be a highly valuable, accurate and effective means of forensic reconstruction which has been used by a number of experienced scientists in the last 30 years to provide forensic intelligence and evidence in selected legislatures [5-7]. The same would be true of any suspects thought to be associated with a crime. Mud found on a stolen vehicle, or a vehicle used in a crime, could link the vehicle with the scene of a crime or link it to the place from which it was stolen. Dirt found associated with other objects or other types of conveyances thought to be associated with a crime also might yield pollen evidence useful in linking those items with a specific crime or a specific geographical location [8]. Pollen and spore exines are amazingly diverse, sometimes even to the species level, and their production is generally seasonally and often geographically restricted, thus their presence can point to a specific season, sometimes even a specific location, in which a crime was committed [9]. There are many published examples of pollen morphology among related families or within families or genera that illustrate this diversity and consequently their usefulness as trace evidence [10-13].

Types of Pollen

Some of the most useful types of pollen and spores for forensics are the wind-pollinated types. This group includes the spore-producing plants such as ferns and mosses, the fungi, and a wide range of pollen types produced by the gymnosperms (nonflowering seed-bearing plants such as pines, cedars, and spruce), and a significant number of angiosperms (flowering seed-bearing plants such as aspen, elms, and oaks). Because wind pollination is a less reliable method of dispersion, these plants must produce vast quantities of pollen or spores that are usually lightweight and are aerodynamically designed to travel easily in air currents. The enormity of pollen production in many of the wind-pollinated (anemophilous) plants is exemplified by statistics such as follows: a single branch of a marijuana (*Cannabis*) plant can produce about 500 million pollen grains, one herbaceous dock (*Rumex*) plant produces a total of about 400 million pollen grains, a single panicle of sorghum grass (*Sorghum*) disperses about 100 million pollen grains, and just one male strobilus on a branch of a lodge pole pine (*Pinuscontorta*) produces over 600,000 pollen grains. In addition to these examples, many of the other wind-pollinated plants such as ragweed, grasses, some species of eucalyptus, filberts, hickory, walnut, birch, alder, and elms produce between 10 000 and 100 000 pollen grains per anther (the part of a flower that produces and contains pollen and is usually borne on a stalk). Other anemophilous plants, some of which are low pollen producers, still produce more than 10 times the amount of pollen per anther and/or flower than almost any species of insect-pollinated plant. The amounts of pollen dispersed annually by the wind-pollinated plants is so vast that their pollen can be found in almost every environment in the world, and the distribution of these pollen types in the pollen rain of each region gives each locale its own pollen signal. As such, each pollen signal contains the pollen types dispersed from the common taxa found in a local area combined with a few pollen types arriving from long distance sources and possible recycled pollen from the fossil record of the region [14]. Some flowering plants live completely submerged in water, release their pollen underwater, and then rely on the pollen to float to the surface or ride water currents in an effort to accomplish fertilization. This method of transport, like the wind, is an inefficient method of pollination; therefore, like wind-pollinated plants, submerged plants often produce high amounts of pollen. These types of pollen might be found on the clothing, in the lungs, in the stomach of individuals who died from drowning, or on a corpse thrown into a lake or stream; however, these types are often of little potential value for forensic work because they decay easily and are difficult to recover through normal extraction procedures. Nevertheless, water bodies are often excellent catchment areas for local pollen deposited from airborne or runoff sources. The largest group of flowering plants is the insect- or animal-pollinated types (entomophilous). This group depends on the transport of pollen grains from the anther (male portion) of one flower to the stigma (female portion) of another by some type of insect (bee, wasp, beetle, moth, mosquito, or ant) or by some type of animal (hummingbirds, lizards, nectar-feeding bats, or other small mammals). The pollen grains produced by these entomophilous plants are generally ornate and often have a surface covered with sticky lipids and waxes or produce fine attached fibers (viscin threads) so that the pollen is easily attached to the bodies of insects or mammal hairs. Unlike most thin-walled and fragile airborne pollen types, these pollen grains generally have a strong and thick outer wall (called an *exine*) that protects them from abrasion during transport and from rapid changes in humidity [15]. Because of the pollination efficiency of entomophilousplants, pollen productivity per anther and flower is much less than that in wind-pollinated plants. In maples (*Acer*), for example, each anther often contains no more than 1000 pollen grains, and in flax flowers (*Linum*), each anther may contain as few as 100 pollen grains. In spite of the low pollen production in mostentomophilous plants, they can often provide some of the most useful forensic clues. Because these pollen types are often large and heavy, and have a sticky surface, they are not usually cast adrift in wind currents and thus are rarely found in the normal pollen rain of a region. This means that it would be unlikely and rare to find these types of pollen grains in the natural pollen rain that falls in anarea. These attributes are both good and bad. Theyare good because if any of these types of pollen grains are found on objects at a crime scene or in other types of forensic samples, or on a suspect, it generally means that the object or the person came in direct contact with the flowers or leaves of the parent plant, or perhaps with the soil directly under the plant containing traces of the plant's pollen. This becomes an advantage because it often means that one can conclude that an item or person was associated with a crime scene or other specific locale of forensic importance. The downside of having to rely on entomophilouspollen is that so little pollen is produced by each insect-pollinating plant that the chances of these pollen grains being transferred from the plant to some foreign object or a person of interest is often reduced. There is also the potential that some of the pollen could have been transported from secondary sources not directly related to the crime scene. Nevertheless, the importance of these types of pollen grains should not be minimized, but a single pollen grain or even several might not provide the compelling evidence needed to confirm the association of an object or person with a crime scene. Instead, it is the total pollen spectrum of any sample, which includes both wind- and insect-pollinated types, and the quantification of these types that provides the essential confirmation of association [16].

Applications of Palynology in Criminal Investigation

Table 1.1 Items from which palynomorphs have been successfully retrieved [17].

A-G	H-R	S-W
Ants' nests	Hair (living and deceased persons)	Sediment
Babies' dummies	Honey and other food	Shoes and trainers
Books and paper	Humus	Skin (living and deceased persons)
Boots	Lawns	Soft furnishings
Clothing	Leaves	Soil
Contents of the lower gut	Mosses	Stomach contents
Decaying plant material and compost heaps	Nasal passages of corpses (turbinate bones)	Stone walls and brickwork
Drug resins	Nylon tights and stockings	Swabs
Dust and dusty impressions on flooring or paper	Paving stones	Tea caddies
Fabrics	Petrol cans	Tools (spades, forks, hoes, rakes)
Faeces	Plant litter	Vacuum flasks
Fences and posts (wooden and metal)	Plant surfaces (leaves, stems, bark, fruits)	Vehicles
Finger nails (of living and deceased persons)	Plastic sheeting and seat covers	Vomit
Fodder	Pot plants	Walls
Fur	Roofs	Weapons
Furniture drawers	Ropes and baskets	Wild animal dens and setts
Ground vegetation		Wooden benches

Palynology as Trace Evidence

Locard's Principle ('every contact leaves a trace') is known to every police detective (White 2004). As outlined above, palynomorphs, especially pollen and spores, are excellent proxy indicators of place. Offenders walk on soil, mud, or vegetation (short and tall); they have been known to hide in, or walk through, hedges, lean against buildings, trees, and posts, or sit on seats. Important evidence has been retrieved from very many objects and matrices and some of these are shown in Table 1.1. If palynomorphs are transferred from a place to an offender, a victim, or any object, they can be retrieved. The transferred assemblage can then be evaluated in terms of the likelihood of the offender, or victim, or object having contacted the specific place (Wiltshire 2004c). Pollen grains have evolved for sticking to the female part of the plant and, unlike fibres (which are readily shed from clothing and other objects), will embed into fabrics and small interstices in footwear and other objects; pollen and spores are not easily removed. They are held firmly by their surface sculpturing and by static charges, and are not easily shed, even from clothing and footwear that have been subjected to washing in a machine (Wiltshire 1997). This quality of tenacious adherence makes them very valuable as trace evidence and indicators of places or specific surfaces. The value and advantages of palynology to forensic investigation are obvious and the discipline proven to be effective. However, it is not simple and the practitioner may need to apply caveats to any conclusion [17].

Source of Trace Evidence

Pollen and spores falling at any one time will be mixed with pollen previously accumulated on the surfaces. Plants (both insect and wind-pollinated) colonising new ground will also contribute to pre-existing assemblages. This means that time is important in forensic sampling. A natural/semi-natural habitat such as a woodland might yield very similar profiles for many years, but there could be drastic changes if the environment were a manipulated one, such as a plantation or garden, even within short periods. Further, any object contacting a palyniferous surface will receive only a fragment of the pollen rain that had accumulated on it over time, and a fragment of the biological signature of the habitat as a whole. This is why it is essential for the palynologist to select target locations within a crime scene. Although trace evidence is transferred to the belongings of offenders when they contact soil and sediments, there have been cases where soil has not played any role in investigations [18,19]. Many surfaces are completely vegetated, or covered in deep leaf litter, such that soil may not be contacted by footwear, clothing, or tools, and vehicles. Plant surfaces, plant litter, humus, and compost can yield dust and, perhaps, the fine fraction of the soil through rain splash and wind action, but the most important particulates will be biological. The investigator must be aware that footwear, the outside of vehicles, and digging implements might be irrelevant to a case and the main source of evidence would be the clothing on the upper body, with no trace of soil. The palynological profile from any crime scene is built up from multiples of comparator samples; it is, therefore, composed of a pattern of fragments. It also follows that, to gain a workable picture of the place, the larger the sampling area, and the greater the number of samples obtained, the closer the results will be to the actual profile (even though that is unknowable in detail). An offender contacting a crime scene will pick up only a fragment of the crime scene's palynological profile. If the trace evidence is then secondarily transferred to, say, a vehicle, only a thirdorder fragment will be retrieved. Palynological interpretation is, therefore, complex and requires visualisation skills as well as an understanding of the complex taphonomy underlying assemblages. In spite of all the caveats that apply, the assemblages distinctive enough to establish convincing links between items, places, and vehicles have been repeatedly demonstrated. As previously stated, palynological samples obtained from exhibits are fragmentary in nature. For links between them and crime scenes to be acceptable to the Court, there needs to be either: (a) a highly complex assemblage where there are many points of similarity between place and object, or (b) some unusual or rare component or components [17].

Mixed Samples: Fabrics

Garments worn repeatedly for considerable periods will pick up palynomorphs from various places, so any retrieved assemblage will be mixed. They are transferred easily from palyniferous surfaces, but few seem to be picked up from air. Except where there is obvious soiling, it is impossible to separate various depositional events by sampling. But, unlike footwear, most items of clothing generally have limited contact with soil, vegetation, and other intensely palyniferous surfaces. As with footwear and vehicles, sufficient comparator samples are needed to be able to eliminate sources other than the crime scene but, if the assemblage accumulated from the crime scene is sufficiently distinctive, multiple deposition need not be an insurmountable problem. A complication with fabric is that an offender may already have had soil on clothing before committing the offence, or after visiting the burial site. Palynomorphs from the crime scene can then be superimposed on the pre-existing soil marks. In one case there was an apparent conflict of evidence where a soil scientist and palynologist were not aware of each other's' roles [20]. Soil on the suspect's sweatshirt was 'innocent', and was derived from deep sub-soil accumulated during the digging of garage foundations; analysis of the soil from the excavation showed it to contain no palynomorphs. While wearing the soiled clothing, the offender buried the victim near a hedge in a pasture. Before the grave was dug, there was little exposed soil in the meadow but, importantly, the offender picked up spores and pollen from tall vegetation on the path to and from the area around the grave site on his soiled sweatshirt. The palynomorph assemblage on the garment was similar to that at and around the deposition site. Thus, if only the soil evidence had been taken, there would have been no link between the garment and the burial site. This case provided a salutary lesson to investigators; the soil analyst and palynologist should work together to gain the deepest level of understanding from the respective data. It is one of the strengths of palynology that pollen grains and plant spores will embed themselves in fabriucs such that they can be retrieved from exhibits even after being put through the washing machine [18].

Mixed Samples: Footwear

Footwear presents another complex of problems and challenges. Usually, samples are taken from specific areas within the crime scene, known to have been walked upon by a suspect, so that they can be compared with palynological assemblages on the footwear. An offender will have had to contact the edge (and inside) of a grave during digging, and a rape victim might be able to locate the exact places trodden by her attacker; samples should be taken from such identified locations. Any footprints or depressions in soil and mud are obvious targets, but these are usually seized by the police for casting and foot mark analysis. It is now standard practice to scrape away the deposit at the interface of the underneath of the cast and the adhering soil layer to obtain the most relevant comparator sample. Even if the offender accumulated layers of soil/mud from elsewhere prior, or subsequent, to the offence, the mixed profile on the footwear should contain some of the trace evidence retrieved from the cast. The palynologist then has to differentiate the relevant profile from the irrelevant one. There has been some attempt to make forensic palynology more 'scientific' by setting up hypothetical crime scenes and testing outcomes from various kinds of contact. Such studies are useful exercises and, for the objects used in the experiment, or places tested, the results might be valuable. However, some results presented, should be considered to be preliminary in view of the low pollen counts in each case, and the limited number of treatments within the trials [21]. It is now standard practice to analyse each item in a pair of footwear separately. In many cases, both feet pick up similar palynological assemblages and it may be thought unnecessary to do separate analysis. However, there have been at least two cases where each shoe differed, and the results were pivotal to interpretation of the cases. In a drugs-related case, an informant claimed that, although he had stood on an area of hard-standing at the edge of a woodland where a grave had been dug, he had not entered the scene and remained standing on an area of muddy concrete about 30 m from the actual grave site [22].

Collection and Extraction of Forensic Pollen Samples

Most forensic specialists want to be the first to visit a crime scene. If the pollen and spore composition of the crime scene is going to be used as forensic evidence, the palynologist should be given access to the area first before pollen information is inadvertently altered, removed, or contaminated by the action of other forensic and crime scene investigators. Allowing personnel unfamiliar with proper crime scene collection techniques to collect forensic pollen samples will sometimes render samples useless for interpretive purposes and/or will provide a basis for the dismissal of such collected evidence in court. Whenever possible, forensic pollen samples should be collected by a forensic palynologist or personnel familiar with proper crime scene procedures and pollen collecting protocol. This type of training for supporting personnel generally comes from working with established, professional forensic palynologists or attending courses or training sessions devoted to proper collection procedures. In all cases, as with other types of forensic samples, it is essential to keep detailed and accurate records and pictures of how and where each sample was collected, the chain of custody of what happened to each sample from the time of collection until it is analyzed, and the security measures used to ensure that all pollen evidence remains contamination free and unaltered. If any hint of contamination, either natural or unintentional, can be implied or proven, then doubt can be cast on the resulting interpretations. An essential part of any forensic pollen investigation is the collection of control and comparator samples. Control samples are samples of surface dirt that will include pollen and spores as well as dust, fibers, soot, minerals, or other materials at, near, or directly associated with a crime scene. The control samples are essential for any forensic pollen study because their contents and pollen and spore spectra provide a "baseline" of information about the "expected pollen and spore assemblage" associated with a specific object or the pollen print from a given crime scene or nearby locale. Control samples are generally composites of a dozen or more small subsamples, or "pinch" samples, of surface dirt collected within a given area and then placed into the same sterile, collection container and thoroughly mixed. The size of the sampled area can be as small as a few square centimeters or meters or as large as several hundred square meters depending on the purpose of the sample. A comparator sample is generally collected from very specific, single locations in and around the crime scene. These samples reflect the pollen and spore spectrum of exact locations, which can later be compared with other evidence suspected of being related to the crime scene. The number of control and comparator samples collected at a crime scene will depend on many factors and on the complexity of the location. As a guide, one should always "over collect" rather than "under collect." Later, all of the collected control and comparator samples from a crime scene might be analyzed, or only a few might later need to be processed and analyzed. However, once a crime scene has been trampled over and altered, collecting additional useful control and comparator samples might not be possible. Once the baseline of expected pollen data can be derived from examining the various control and comparator samples, then the pollen recovered from a suspect or from forensic specimens thought to be associated with the crime scene can be compared against the control and comparator data to see whether there are similarities. Knowing how many control samples to collect from the scene of a crime is often a difficult task. The more control samples one collects, and examines, the more pollen information one has about the locale where a crime was committed. Because the pollen spectrum in each control sample may vary slightly in reference to pollen types and percentages of each type, their combined spectra offer a potential range of pollen variation that can be expected for the actual crime scene. These types of data make matching the pollen results found on objects or suspects thought to be associated with a crime scene either convincing or obviously not similar. Not having control samples from the right locations or not having an adequate number of control samples from a crime scene can prevent a forensic palynologist from knowing what pollen types, and in what percentages, he or she should "expect" to find at the crime scene location. Sometimes, control samples need to be collected from both sides of a path or walkway or from series of closely spaced areas in and around a crime scene. Without this type of precise knowledge, it becomes difficult to argue either for or against theassociation of the pollen assemblage found on asuspect's shoes, car, or clothing with the pollen types found at the actual crime scene. One cannot collect too many control samples from a crime scene because once the area has been disturbed by other crime scene personnel, additional sample collection is often unreliable due to the possibility of outside contamination. Once all control samples have been collected, they should be stored in contamination proof containers that are clearly marked and then placed in cold storage near 0 ◦C to prevent possible microbial damage or destruction of pollen in the sample. Low temperatures or even freezing samples will not damage the pollen or spores in a control sample but it will stop or retard microbial activity until the samples can be analyzed. Other alternatives include adding a small amount of alcohol or some other microbe deterrent to the sample as long as it does not interfere with preservation of the pollen and spores. One question that is sometimes raised during investigations or in court focuses on whether or not two different locations can present identical pollen spectra. The possibility of this occurring is highly unlikely, and thus far, an identical match of pollen spectra from two different locations has not been proven to occur. The unlikeliness that this possibility could occur depends to a degree on how large a pollen countone attempts. Minimal pollen counts of only a few hundred pollen grains might suggest that two different samples appear nearly identical in terms of their pollen signatures. However, as the number of pollen grains and spores counted in a sample increases, the potential of two different samples providing nearly identical pollen spectra disappears. Analysis of forensic samples depends on the diversity of both pollen and spore taxa as well as the quantitative relationship of each taxon to all others. One example that illustrates the importance of collecting adequate numbers of control samples focuses on samples collected from the ground where a sexual attack occurred. A forensic pollen study of the woman's soiled clothing matched the pollen types found in the control sample of one specific location confirming that she had been attacked at that precise location and had struggled with her assailant. Later, asuspect was identified and a search warrant revealeda soiled shirt and pants containing a pollen spectrum that matched the control sample collected from the exact location where the sexual attack occurred. The pollen evidence alone did not confirm the suspect was guilty, but it did corroborate that he had been at that precise location, which was in a location where he said he had never visited [23]. Often a forensic palynologist has only a very small amount of material available for analysis. A few examples that I have examined in the past include the dust collected from the top of a table, a tissue wipe from the surface of a sandal, a piece of crumpled wire taken from an explosive device, dust collected from the surface of a cell phone, dust trapped in the keyboard of a laptop, a piece of tape used to wrap a package of illegal drugs, one shoelace, a tiny piece of torn tissue no larger than a postage stamp, a sticky tape of dust collected from the dash of an vehicle, small tuffs of human hair from a body, the dust caught on the windscreen of a car, dust from air filters, and pollen and spores vacuumed from various items including clothing. Sometimes, when I have been fortunate, I have examined pollen trapped in socks, dirt trapped in the tread of a shoe, or dirt caught in the carpet of a car. Once, the pollen recovered in the tiny bits of "fuzz" trapped in the bottom of the pockets of a pair of corduroy pants helped resolve where a murdered victim had lived. There is almost no limit to what types of pollen and spore samples one can collect as potential evidence for use in cases related to forensic studies. Nevertheless, often these types of samples create two major challenges for the forensic palynologist. First, there will rarely be enough material in a sample to try different extraction techniques. Second, there is rarely enough material to conduct a second test if something goes wrong during the initial pollen extraction and recovery process (e.g., centrifuge tube breaks, a beaker spills, a sample is dropped or accidentally mixed, a microscope slide breaks, *etc*.).

For these reasons, the pollen extraction and recovery process must be conducted with utmost care. In addition, in an effort to remove and concentrate the durable pollen and spores in forensic samples, it is generally necessary to destroy all of the non-pollen components. This means a sample'smatrix will not be available later for other types of forensic testing. Studies of the DNA, isotopes, other trace elements, hairs and fibers present, or the composition of dirt and sand in a forensic pollen sample must be conducted before pollen extraction occurs. Such ancillary studies, however, must be completed carefully and must not increase the risk of potential pollen contamination in the sample. Almost anything can be tested for forensic pollen. Dirt and dust trapped in almost any object often contain pollen and spores from the locale where the object originated or was used. The following case illustrates this point. In New Zealand, a man robbed a store and escaped on a motorcycle. Police gave chase and almost caught the thief, but at the last minute, the thief abandoned his motorcycle and ran up a muddy hill and escaped into a wooded area. The next day, a man identified the motorcycle as his and told the authorities that it had been stolen the day before. The police realized that the owner closely resembled the suspected thief. Armed with a search warrant, the police recovered a pair of muddy boots owned by the suspect. When asked about the mud, the suspect said that the mud came from the farm where he worked and denied that he had ever been in the area where his motorcycle had been abandoned. A forensic palynologist collected a series of control soil samples from areas on the farm where the suspect worked and examined them to obtain a pollen print of the farm region. Next, the palynologist collected a series of control soil samples from the muddy hill where the motorcycle had been abandoned and examined them for their pollen contents. Finally, after examining the pollen trapped in the mud on the suspect's boots, the palynologist could confidently say that the pollen assemblage matched the pollen print from the muddy hill and not the pollen spectrum of the control samples examined from the farm [24]. This type of forensic sample discrimination between two or more different locales is one of the common ways in which pollen evidence is being used to aid in criminal investigations. Clothing becomes an ideal trap for pollen and spores. Clothing made of wool, linen, and cotton are among the best pollen traps, whereas garments made of leather, nylon, rayon, and other types of materials are less effective as potential pollen traps [25].

Application of Forensic Palynology

The study of pollens in forensic problems has helped in solving several cases of murder, rape, etc. In India, however, this important area has not received much attention. If due attention is given to this important aspect many cases of adulteration of food and other eatables such as honey, milk, etc. and cases of rape, murder, kidnapping can be solved easily. Pollen evidence has also become significant in determining the manner and time of death, source of origin of illegal drugs and their route through which it has probably been transported. Although palynology has so far been neglected, it is hoped that sooner or later, forensic palynology will be used in several crime solving exercises especially in cases of rape, bestiality, murder, illegal drug trafficking etc. when other evidence may not be available [26]. Palynological samples can be recovered from a wide range of sources, including people, such as on their clothes, in their hair or even in their nasal passage, vehicle tyres, air filters in cars, on objects and in mud. Because of the dispersal mechanisms of some plants, pollen can be readily picked up and transferred. A person can easily inadvertently pick up pollen from a crime scene, whether it be in mud on their shoes or on their clothes from directly brushing against a plant in the area. With this in mind, a primary use of palynology in a forensic investigation is to establish a link between two places, objects or people. For instance, it may be possible to link a suspect to an object, a vehicle to a crime scene, or even link two separate incident scenes. If a suspect was present at a particular crime scene at which pollen can be found (for instance a field or garden), they may have picked up pollen on their clothing or in their hair. Because pollen is so resilient, it can often stick to other objects even after that object has been washed. If the pollen recovered from the suspect matches pollen collected from the crime scene, this could suggest that the suspect was in fact present at that scene. However, it must be considered that although the presence of pollen may establish a link, the lack of pollen does not necessarily prove that there is not a link. Similarly, palynology may be able to determine the location of a crime scene if it is not known. For instance, a body that is believed to have been moved may carry pollen grains that can be analysed and traced to a likely location. This may particularly be suspected if the body carries large amounts of a particular pollen that is not found at the location in which the body was found. The study of pollen can also be used to determine the travel history of an item. In some cases it may be necessary to ascertain where an item has originated from, especially illicit drugs, money, antiques and even food. By analysing pollen recovered from suspect items, it may be possible to trace that item to a particular country if the pollen grains identified are sufficiently distinctive. Although this application of palynology may not necessarily be able to establish an exact location, it may be least be possible to rule out certain geographical locations and point the investigation in the right direction. It may even be possible to estimate the time of year at which a crime took place. In the investigation of a somewhat older crime scene, pollen collected may actually be released at a different time of year, indicating the crime occurred during this period. Of course despite the links palynology may establish, further evidence may be needed to support any conclusions reached. Pollen recovered from a suspect that happens to match that of a crime scene may simply suggest that the individual had visited that area at some point recently, not necessarily prove that they have committed a crime. Although forensic palynology has been utilised for decades, it is unfortunately not widely accepted as a reliable forensic technique, instead frequently seen as a last result failing more ‘standard’ investigative techniques. In addition to this, there are very few people properly trained to analysepalynological samples, thus samples are often collected and handled by untrained staff, inevitably leading to issues of sample preservation and contamination [27].

Discussion or Forensic Significance

Spores and pollens have more significance from many other biological sources of forensic evidence. the significance of pollen grains is that they are so small, between 7–200 micrometers (avg. 20–60µm), that they cannot individually be seen by the naked eye, thus criminals cannot tell that they have collected them from the crime scene. crime enforcement agencies developedof the potential value of forensic pollen work, the need for qualified personnel in this field will increase and will provide the emphasis needed to encourage the establishment of training centers for these specialists. Palynological samples can be recovered from a wide range of sources, including people, such as on their clothes, in their hair or even in their nasal passage, vehicle tyres, air filters in cars, on objects and in mud. Because of the dispersal mechanisms of some plants, pollen can be readily picked up and transferred. A person can easily inadvertently pick up pollen from a crime scene, whether it be in mud on their shoes or on their clothes from directly brushing against a plant in the area. Although forensic palynology has been utilised for decades, it is unfortunately not widely accepted as a reliable forensic technique, instead frequently seen as a last result failing more 'standard' investigative techniques. In addition to this, there are very few people properly trained to analyze palynological samples, thus samples are often collected and handled by untrained staff, inevitably leading to issues of sample preservation and contamination.

Conclusion

Worldwide, palynology is an under-used resource for criminal investigation. This is due, in part, to the perennial dearth of competent palynologists who possess not only comprehensive botanical knowledge, ecological training, and appropriate and extensive field experience, but who can cope with the rigours of cross-examination in the courts. Pollen evidence can also disclose the season in which a specific object picked up the pollen. pollen grains are present in the air, they constantly settle on surfaces and they are a significant cause of hay fever. Pollen is incredibly differential and thus positively indicates where a person or object has been. Its distinctive differences are hugely dependent on both the varying regions of the world and particular plant species. Pollen can also reveal the season in which a crime was committed as well as in the tracing of mass activity.Pollen is often microscopic and even after washing clothes, pollen can remain in pockets or cuffs which allows the evidence to be collected even up to long periods after the event.

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