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Role of Analytical Techniques in Crime Investigation

Asif Ibrahim[1] and Syed Khurram Hassan[2]
[1] Department of Mathematics, FC College University, Lahore.
[2] Institute of Quality and Technology Management, University of the Punjab, Lahore, Pakistan.
Corresponding author:khuramshah6515@gmail.com
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Abstract
Forensic science is becoming a growing discipline in crime scene investigation. The field of rhetorical science has recently undergone an intriguing evolution and significantly raised its public visibility. Advances in science and technology, increased dependence on law enforcement and court systems science, and media exposure have all contributed to the importance of forensic. Several completely unrelated fields have been associated with the name "forensics". Among the topics that commonly make the headlines are acts of terrorism, a rise in gun ownership, drug misuse, and driving while under the influence of narcotics. The forensic scientist must rely on chemical analysis of trace amounts of materials such as drugs, explosives, discharge residues, toxicological specimens, paints, glass, fibres, soil, etc. to establish or rule out links between suspect and victim and scene in the absence of fingermarks and of material that could lead to the recovery of DNA. This instructional overview outlines the analytical issues that forensic chemists must deal with, as well as the current approaches and strategies used to solve them.
Keywords: Techniques, forensics, DNA, Toxicology, fingerprints

1. Introduction

Now, the public in general has grown more awareness of how science is used to solve crimes, as a result of the rise in both fictional and documentary television shows [1]. Among the topics that commonly make the headlines are acts of terrorism, a growth in the illicit use of guns, drug trafficking, and driving while under the influence of narcotics [2]. Since the identification of person-specific human DNA "fingerprints" and the subsequent forensic use of DNA fingerprints in 1985, forensic science laboratories have invested a significant amount of money in the creation of DNA profiling techniques. Evidence makes it as advanced tool for identification [3]. According to Forensic Technology Survey's findings and related case studies, there is an urgent need for more advanced forensic science technology, as well as for qualified people to utilize it and communicate its findings [4]. Major conclusions include that numerous crime laboratories have a sizable backlog of evidence that has not been analyzed or otherwise processed [5]. No matter how careful a criminal tries to avoid leaving his fingerprints, he may still accidentally touch other areas of his body and leave bodily fluids or tissue behind, each of which will contain his DNA. In crime scenes, fingerprints are also person-specific [6]. However, forensics experts should indeed focus solely on chemical evaluation of trace quantities of materials such as explosive devices, stimulants, glass, soil, etc. to develop links between victim and suspect [7]. This study will look at the most recent approaches to forensic analytical chemistry for the categories of evidence mentioned above. The case become more prompt if effective forensic scientific skills are available.

2. Process Used By a Toxicologist

Three steps may be identified in the procedure toxicologists use. In the first, the medicines, metabolites, and other relevant analytes are tentatively identified using qualitative analysis. These are identified through screening tests, same like with narcotic examination of confiscated goods. But the narcotics chemist who was apprehended has fewer alternatives. There are two reasons for this restriction. The sample matrices come first and are more significant [8].

3. Drug Analysis

The most often abused narcotics amphetamines, heroin, benzodiazepines, cannabis, cocaine are the substances that a forensic drugs analyst is most likely to come across [9]. They can be found in small amounts in the hands of individual users as so-called "street seizures," in greater amounts in the hands of local drug traffickers, and in kilogramme quantities as imported substances. The basic objectives of the forensic scientist's analysis are to: (a) establish if a prohibited substance is present, (b) establish the quantity of the substance, and (c) occasionally establish the link between drug samples by comparison or "profiling" [10]. For quick screening and straightforward comparison, thin layer chromatography (TLC) is used on ethanol extracts of the resin, herbal material and oil [11]. Profiling can be done using GC-MS or HPLC. Reversed-phase HPLC will establish if the resin blocks came from the same batch based on the results of the preliminary TLC screen. HPLC is helpful since, unlike GC-MS, it does not call for derivatizing the materials. Because they are thermally labile, tetrahydrocannabinolic acids would break down under GC-MS conditions. The drug profile is shown by the chromatogram [12].

4. Explosives

The removal of explosive residues or traces can be done using sticky tape, solvent cleaning of objects, vacuum sampling, or swabbing (dry or with a solvent) [13]. Ion mobility spectrometry is a quick and practical screening procedure at the crime scene or in the lab (IMS) [14]. Explosive remnants from questionable surfaces are collected using a suction using a portable IMS device. [15]. Prior to colour spot tests and chromatographic analysis, residues submitted to the lab are first inspected under a microscope.They are then dissolved in a solvent such ethanol or acetone. The most popular analytical system combines mass spectrometry's (MS) identification capabilities with HPLC's separation capacity [16].

Based on Locard's Exchange Principle, forensic investigation of any trace evidence, including textile fibres, is performed [17]. According to this, "every contact leaves a trail." In reality, even though there has been a movement of material (in one or both ways), it might not be feasible to tell because of how little was really moved. Additionally, some surfaces may swiftly and readily lose transferred material due to their nature and texture. As a result, it's critical to gather clothes from suspects and victims as quickly as possible after an alleged crime since recent transfers are frequently involved in proof of touch (and hence affiliation) discovered by comparison of fibres.

When fibres are readily visible, forceps, lifts with sticky tape, or suction are used to recover or retrieve them from a crime scene [18]. Microscope comparison, fibre identification, and colour analysis are all steps in the study and analysis of fibres. UV/visible comparison microscopy is used to compare known or control fibres to extraneous (suspect) fibres that have been collected loosely or from tape lifts [19]. It is possible to identify whether a fibre is synthetic or natural using morphological information from optical microscopy, whereas synthetic fibres may be identified using pyrolysis gas chromatography (PGC) and pyrolysis mass spectrometry (PyMS). Visible light microspectrophotometry is used to check known and suspicious fibres for similarities following comparison microscopy [20]. If the resultant spectra are comparable, an FTIR analysis is performed, which provides a clear identification of the fibre polymer as well as some information on the dyes. The procedures utilised for dye extraction will vary on the kind of fibre and colour being employed. Visually like colours could really be made up of many component dyes (a so-called "metameric match") that are easily distinguishable by TLC, HPLC and Surface Enhanced Resonance Raman Scattering (SERRS) have been successfully employed [21].

5. Paint

Paint can be found as an evidence in a variety of situations. It may appear as tiny peels on the clothing of someone who has vandalised a building and damaged the paintwork, as paint streaks transmitted from one car to the other in a collision, or from a car to a victim in a hit-and-run accident [22]. Beginning with a microscopic inspection of control paint, such as that from the place of entry in the instance of a break-in, the analytical method to such evidence is used (found on the garments of the suspect). In addition to visible light microscopy, polarised light microscopy are used because they can provide a wealth of information about the general appearance of the samples.This also includes the existence of a layer structure, the texture and color of the layers, information on particle size.Since single-layer forensic paint specimens are the norm, it is necessary to identify the chemical makeup of the extenders, binders and pigments after comparing colours [23]. X-ray powder diffraction (XRD), X-ray fluorescence (XRF), and scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) are used to analyse paint pigments and extenders. Because it can do elemental analysis and offers a magnified view of the paint flake specimen, scanning electron microscopy is very helpful. An elemental analysis can be accomplished by focusing the electron beam directly on certain paint layers and individual particles. It is possible to infer the quality of pigments present in the material, however SEM/EDS by itself cannot identify the pigments with certainty.Although multilayer paints require layer separation before examination, XRD is a good non-destructive method for analysing paint since it does offer conclusive identification of the pigments (organic or inorganic) and extenders [24]. Its relative insensitivity in compare to the other approaches is its main flaw. Elements have also been analysed using laser ablation inductively coupled plasma-mass spectrometry (LA-ICP-MS). Prior to ICP-MS analysis, the laser ablation method can concurrently sample numerous layers in order to identify and quantify trace elements that are present in various layers of the sample. A new method of discriminating is added via trace element analysis. Pyrolysis techniques like Pyrolysis Gas Chromatography (PGC) and Pyrolysis Mass Spectrometry are used to analyse the binders in a paint material [25].

6. Fibres

Target fibre investigations demonstrate that practically all fibres only sometimes appear in the environment, as was previously noted. Indigo-dyed cotton would be the most notable exception. This suggests that the degree of linkage is likely to be high if well-known and unknown fibres are comparable overall in physical and chemical properties. This may not be the same as personalising the evidence. Only a tear match can differentiate between fibres. In addition to the previously mentioned, fibres (and hairs, too) have the shared characteristic of being easily transferred from one substance to another or from a material to a different surface, like a chair seat. The transmitted fibres may stay on the destination item or may just be transferred again [26].

7. Fingerprints

The finger markings, which are the impressions made by the friction ridges of the finger. These fingerprints not only show that the surface or object was touched, but they also help to identify the individual. Latent, patent, and plastic fingerprints are the three types that are most frequently discovered [27]. Almost all crime scenes contain latent prints, which must be processed since they are difficult to see with the human eye [28]. A wide range of physical and chemical techniques have been developed to decode the latent fingermarks. The most popular technique for creating latent fingermarks is powder.The best fingerprint powder will attach to the finger sweat residues, which produce the distinctive patterns that transform latent prints into coloured or fluorescent visible prints depending on the type of powder used. It is much more difficult to make a definite identification since many common materials stick to the backdrop [29]. In order to solve these issues and increase precision, nanotechnology is being employed to build fingerprint.The fingerprint pattern has been deciphered using tiny particles. Numerous research have shown that nanopowders may be used to decode fingerprints, and most recently, one of these studies found that zinc oxide powders with a 20 nm particle size produce superior prints and UV fluorescence than other powders. Additionally, their newly created techniques operate in moist conditions where conventional powders cannot [30].

8. Glass

Globally, Glass has potential applications. As a result, it frequently occurs in violent crimes including murder, robbery, planned car accidents, and reckless driving. When glass breaks, tiny pieces might become stuck to the offender's clothing or weapons. These pieces can be used as significant evidence in court proceedings if they are gathered, examined, and compared.It has also been done to analyse glass samples using both elemental analysis and RI determination. The majority of these investigations have come to the conclusion that these analyses are complementing rather than rival. Metals in glass samples may be analysed using inductively coupled plasma-atomic emission spectroscopy (ICP-AES) and inductively coupled plasma-mass spectrometry (ICP-MS). However, their primary drawback is their destructive nature, which has led to Laser Ablation-ICP-MS largely replacing them (LA-ICP-MS) [31]. Glass samples may quickly be directly analysed using a quasi-non-destructive approach. Other studies have using X-Ray Fluorescence (XRF) methods. XRF has a non-destructive nature, is simpler to operate, and costs less than ICP-MS. Due to its speed, lack of sample preparation requirements, and similar sensitivity to LA-ICP-MS, Laser Induced Breakdown Spectroscopy (LIBS) has recently gained popularity. Although to a lesser degree, glass examination has also been performed using the scanning electron microscope energy dispersive X-ray spectroscopy (SEM-EDX), particle free induced X-ray emission (PIXE), and the electron probe micro-analyzer (EPMA) [32][33].

9. Arson

The most common accelerants used in arson assaults are gasoline (also known as gasoline), paraffin (also known as kerosene), and occasionally paint strippers.After the flame has been extinguished, any remnants of these substances may quickly vanish.The method that is most frequently used to analyse evidence of accelerants found at fire sites is gas chromatography (GC) [34]. The bags or jars containing the trash and garments are sampled from headspace to begin the examination. Any volatile residue is driven into the container's atmosphere by heating it.A syringe containing an absorbent material, like the resin Tenax, is used to pull the air comprising volatile compounds through the resin [35]. The absorbent substance is forced through the storage container into the surrounding air. Volatiles that have been absorbed are thermally exfoliated from the Tenax when the cuvette is inserted in the GC. As a result of the heating action of the fire,A mixture of peaks from the accelerants and any pyrolysis byproducts from the heat degradation of polymers and natural materials will appear in the resulting chromatogram. When residues are retrieved from a fire scene, the more volatile parts of petrol are not present, which at first may make identification more difficult. However, comparison with chromatograms of conventional paraffin, diesel,white spirit and diesel will typically identify the accelerants [36].

10. Coclusion

Forensic science applications can lead to distinct identifications in different ways. In situ trace analysis using Surface Enhanced Resonance Raman Scattering Spectroscopy (SERRS), which is practically non-destructive, also has a lot of promise. SIRMS and SERRS will undoubtedly advance, becoming important analytical techniques for determining, respectively, the source and composition of materials such as drugs, dyes, glass, fuels, soils ,inks, glass explosives, and and many others. This is similar to how DNA profiling will undoubtedly continue to advance.

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