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Analytical Instrument in Trace Evidence Analysis used in Forensic Sciences

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Abstract

In the present paper, we explain the importance of the analytical instrument used in the field of forensic science for the analysis of the trace evidences collected from the scene of occurrence. The forensic scientist has to rely upon these instrumental analyses of trace amount of materials like drugs, toxicological specimens, GSR, fibers, glass, paints, soil etc. Variation in the manufacture of chemical composition and allows considerable discrimination even with very small fragments are observed. More emphasis on GSR, Sometime GSR analysis become very important to get a proper direction of investigation, from where the GSR is collected and from which surfaces the GSR accumulated, played an important aspect of investigations. Through this paper, reviews on these techniques which are extensively used in forensic sciences have been reported. Our report summaries on the basis of analytical problem facing for a forensic expert and techniques employed to tackle them like chromatography, XRD/XRF, inductively coupled plasma (ICP) techniques, Raman spectroscopy and microscopy (optical, , GRIM, electron microscopy) etc.

Introduction

The analysis of a crime scene involves the participation of experts in both the physical and biological sciences as well as in many areas of technology and law enforcement. Forensic chemists study fingerprint patterns and fiber, glass, gunshot, and other types of residues; analyze drugs and poisons; examine possible forgeries; analyze residues for possible arson and explosive crimes; and carry out DNA analyses to identify possible criminal suspects.

Today the term Criminalistics is often used to describe the work that forensic chemists and other forensic scientists do. The term means virtually the same as does the more common phrase forensic science. Some number of examples will be presented that illustrate the ways in which forensic chemists can contribute to the solution of crimes, with special emphasis on recent developments in techniques they use and the methods. In this paper, we have tried to explain the available analytical instruments available for analysis of trace evidence analysis.

Toxicological chemistry examination using different Chromatography

In almost all experimental studies in toxicology, an agent, generally a single chemical substance is administered in known amounts to an organism. It is universally acknowledged that the chemical under study must be pure or the nature of any contaminants must be known to interpret the experimental results with validity [1]. However, it is common practice to proceed with the experimental study without verifying the purity of the compound. A scheme of separation for poisons from tissues by steam distillation and differential solvent extraction is shown in Figure 1. The analytic techniques initiated by forensic toxicologists have continued to expand in complexity and improve in reliability. Many new analytic tools have been applied to toxicology problems in almost all areas of the field, and the technology continues to open new areas of research [2].

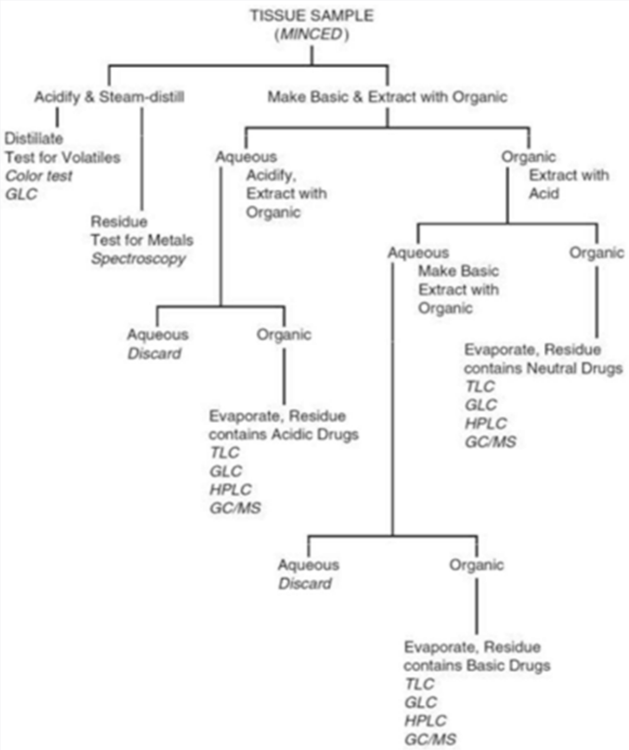

Figure 1: Flow chart for separation of poisons from tissues available in literature [1].

Elemental Chemical analysis using XRD/XRF

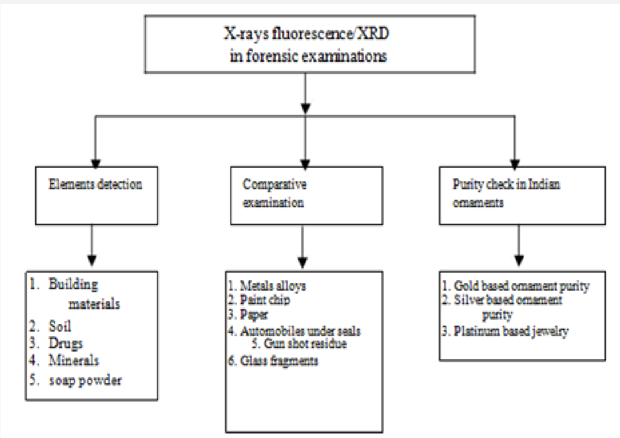

Figure 2: Summary of use of X-ray techniques in forensic sciences [6].

The x-ray fluorescence (XRF)/ X-rays Diffarction techniques have been used in forensic science for several decades [3]. Unlike many other analytical techniques, XRF does not affect samples as it is a non-destructive method [4,5]. This alone can be extremely valuable as certain specimens require confirmatory analysis by another group of scientists to validate integrity of the data. Forensic science involves the application of science to law. In numerous criminal cases, forensic scientists are often involved in the search and examination of physical traces. This evidence can be useful for establishing (or debasing) a link between suspect, crime scene, and/or victim. The physical traces can commonly include paint flakes, glass fragments, fibers, slivers of metal, soils, building materials, stains of any description, corrosion products, loose powdered materials, gunshot residue (GSR), etc [6-8]. Possible applications of the XRF/XRD technique on different kind of forensic samples are summarized in the Figure 2.

Inductively coupled plasma (ICP) mass spectrometry technique

The discrimination of sheet glass exposed to high temperature by the determination of trace impurities using ICPMS was reported. The determination of iron in glass by laser ablation and solution sampling comparing dynamic reaction cell-ICPMS and high resolution (sector field) ICPMS was also reported [9]. Several reports on the analysis of glass by LIBS, including a comparison of the results from LA-ICPMS, µXRF, and LIBS for the analysis of the same set of samples [10], the comparison of different irradiation wavelengths for the analysis of glass [11], and two other research studies on the application of LIBS to glass analysis [12] were published.

Raman Spectroscopy Techniques

There has been resurgence in Raman spectroscopy for its application in forensic science. This method allows for the measurement of the inelastic scattering of light due to the vibration modes of a molecule when irradiated by an intense monochromatic source such as a laser. The Raman technique presents advantages such as its non-destructive nature, its fast analysis time, and the possibility of performing microscopic in situ analyses. In its forensic application, it is a versatile technique that covers a wide spectrum of samples such as drugs of abuse, trace evidence, fibers and inks. Instruments characterized by a high sensitivity and coupled to light microscopes supply a high potential for the micrometric and in situ analysis of many types of materials of forensic interest. The analysis of textile fibers constitutes a clear example. In this field several studies have been carried out (e.g. Bouffard et al. [13]; Keen et al. [14]; Miller and Bartick [15]; Jochem and Lehnert [16]; Thomas et al. [17]. The usefulness of this technique for the forensic analysis of fibers mainly focuses on the detection of dyes.

Microscopy and Electron Microscopy

Microanalysis is the application of a microscope and micro scopiea \ techniques to the observation, collection, and analysis of micro evidence that cannot be clearly observed or analyzed without such devices. Microanalysis today generally deals with samples in the milligram or microgram size ranges. Microscopes and the techniques to be discussed will be limited to those that employ light in the visible, ultraviolet (UV), and infrared (IR) frequency ranges or use electrons for illumination. Analysis with a microscope may be limited to observations of morphology or involve the collection of more sophisticated analytical data, such

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as optical properties, molecular spectra, or elemental analysis [18,19]. A wide verity of microscopes is available for use in a forensic laboratory and they can examine a wide variety of materials.

Traces such as fragments of glass, paints or gunshot residues most often occur in very small quantities. Thus, sensitive analytical methods are required in order to obtain satisfactory results from small amounts of sample. For the selection of proper analytical methods one should take into account the fact that the method is not allowed to destroy the samples because the material might be re-used. One of these non-destructive methods is scanning electron microscopy with an energy dispersive X-ray spectrometry (SEM–EDX) [18]. It is a powerful tool for forensic purposes because one can examine objects considering their morphology and the elemental composition. Moreover, the obtained results can be evaluated by using suitable methods of chemometric analysis [20]. The paint coat of a car body consists of a number of successively overlaid paint layers. These layers differ from each other in terms of their ingredients, i.e., resin, pigments and fillers. The number of layers making up a car covering depends on its type. In brand new cars and in those that have not been repainted there are only three to four layers. Paint coverings of renovated cars consist of a larger number of layers (sometimes even more than a dozen), including not only enamels, but also putties, painters' putties and ground undercoats. In identification and comparative studies of paint chips, scientists define their macroscopic properties colour, shade and texture and their microscopic properties relating to their morphology [21]. SEM measurement have also been reported on fiber and hair sample by Sharma and Jha [22].

Emphasis on GSR analysis

Few experienced experts all over the world undertake the task of identification of the type of ammunition taking into account the qualitative differences in chemical composition of GSR (personal communication R Keeley, London Metropolitan Laboratory, Forensic Science Service, 1997). Attempts at an objective and systematic approach to that analysis as systematic study of gunshot residues originating from selected types of ammunition by means of SEM-EDX and utilization of chemometric methods for interpretation of the obtained results were presented by Niewoehner [23] and Broiek-Mucha et al. [24,25]. In their first work was basically based upon quantitative analysis of one hundred particles arbitrarily chosen from all of the preserved gunshot residues from different components of bullet (i.e. including the primer, case, projectile, projectile jacket etc.), whereas in the last two publications frequencies of occurrence of primer particles of particular chemical classes were taken into account and experimental study were performed. Through those both attempts results revealed the possibility of group identification of the ammunition used based on GSR study.

It is worthwhile mentioning that a growing attention is being paid to chemical composition of gunshot residue originating not only from the primer, but also from the propellant [26-29] and the projectile [30]. More sensitive than SEM-EDX, analytical techniques are being introduced also to study the chemical content of primer residue such as Inductively Coupled Plasma Mass Spectrometry (ICP-MS) [31,32], providing more discriminative data. However, only SEM-EDX is the most specific for GSR analytical method providing information on both, their morphology and the main elemental contents thus remaining a reliable tool for GSR examinations [33-35].

Discussion

The analytic techniques initiated by forensic experts have continued to expand in complexity and improve in reliability. Many new analytic tools have been applied to analytical problems in almost all areas of the field, and the technology continues to open new areas of research. Over the last two decades, a new analytical tool has been developed. Forensic examiners continue to be concerned about conducting unequivocal identification of toxic substances in such a manner that the results can withstand a legal challenge. The problems of substance abuse, designer drugs, increased potency of therapeutic agents, and widespread concern about pollution and the safety and health of workers present challenges to the analyst's skills. Today investigators have a wide range of analytical tests and sophisticated equipment with which to study microscopic pieces of evidence collected at such crime scenes. As disgruntled individuals and terrorists continue to use fire and explosives to disrupt society, forensic chemists will go on developing methods for identifying the persons responsible for such events.

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