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United Nations Office on Drugs and Crime

Staff skill requirements and equipment recommendations

for forensic science laboratories

Laboratory and Scientific Section
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Contents

INTRODUCTION

Forensic science capabilities and facilities, from the crime scene to the court room, provide accurate, objective and timely information not only to law enforcement agencies and the criminal justice system, but also to regulatory and public health authorities. Forensic science is a major component of objective, fair and transparent criminal justice systems. It is used for traditional court evidence to build cases based on physical evidence rather than on confessions and witness testimony. Consequently, it supports effective and fair criminal investigations and proceedings. Forensic science is also part of the investigative process for operational crime analysis and intelligence.

The constantly changing pattern in both conventional and organized crime, including all forms of trafficking, has led in recent years to increased interest on the part of Governments and the international community in establishing or strengthening quality forensic science services at the national level. While examining existing resources to ensure the availability of both the skills and equipment necessary for effective forensic science facilities, the United Nations continue to receive a range of requests for advice and assistance concerning the training of staff and the selection of appropriate equipment and reference material.

The present manual was developed in response to these requests and aims to provide practical assistance for the establishment or upgrading of national or regional forensic science infrastructure, including crime scene investigation capacity, drug analysis laboratories, general forensic science facilities and law enforcement technical departments. This manual provides checklists of required staff skills and recommended equipment for an adequately equipped and staffed forensic science infrastructure.

This information contained within this manual will have its greatest impact if:

- A careful assessment of existing resources and requirements is carried out prior to using the manual, in order to optimize existing laboratory services at the national and regional levels, to avoid interagency rivalries and costly duplication of expensive items of equipment and dissipation of technical skills, and to identify capability and resource gaps. This assessment is fundamental as not all of the equipment listed in this manual is necessarily required in every forensic science laboratory. The equipment requirements for each laboratory will vary depending on the availability of other scientific and laboratory facilities on a national or even regional basis, on local crime trends, and on current workloads. Detailed guidelines for assessing national forensic infrastructure are available.[1]

- A step-by-step approach is applied when introducing new or upgraded equipment. This is indispensable to ensure that available technical skills are commensurate with the choice, acquisition, use and maintenance of the equipment. Wherever compromise is necessary, one should keep in mind that ensuring and enhancing the capabilities and competence of the scientific staff is far more important than acquiring the latest equipment.
- Adequate resources are made available to maintain existing equipment, to provide for the continued replenishment of consumables, to enable the laboratory to develop its staff (e.g. by providing for scientific society memberships, professional meeting attendance, research, and publications), and to participate in relevant proficiency tests.

ORGANIZATION AND USE OF THE MANUAL

The manual consists of three parts, two annexes and a bibliography. It is intended to be used as a checklist to provide guidance on the staff skills, training needs, equipment and accessories required for establishing, upgrading and/or maintaining services in one or more forensic fields (disciplines). The manual is designed to allow the user to focus on forensic science fields of their choice and to use only the corresponding, relevant sections. It is divided as follows:

Part I — lists staff skill requirements. It starts by outlining the general staff skill requirements common to all forensic science fields, followed by the skills required to recognize, document and recover physical evidence from crime scenes. Finally, it lists the specific requirements to perform laboratory examinations and analyses on the various types of physical evidence.

Part II — lists equipment, materials and accessories related to the different techniques utilized. It starts by recommending techniques for providing a minimum service in each forensic science field, followed by detailed lists of equipment and accessories. Each section is complemented by an enumeration of the skills related to the proper operation of the equipment. Relatively expensive equipment and consumables that have to be regularly purchased are marked throughout part II.

[1]Module on "Forensic Services and Infrastructure" of UNODC's Criminal Justice Assessment Toolkit; accessible at: www.unodc.org/unodc/en/scientists/criminal-justice-assessment-toolkit.html

Part III	provides some general considerations to be taken into account when designing and establishing a forensic science laboratory.
Annex 1	presents an overview of the various techniques and their fields of application in forensic casework. Techniques that are mainly used for research purposes are not included. Annex 1 is comprehensive for a well-equipped laboratory environment, but serves also as a basis for minimum equipment recommendations when commencing casework in a selected forensic science field.
Annex 2	provides additional guidance in the form of a classification of the various techniques (independently of the field in which they are applied), using the following parameters: the initial purchase and running costs, the infrastructure requirements, the complexity of operating the related equipment, and the skills required for meaningful interpretation of the results.
Bibliography	suggests books and other reference materials, taking into account not only the role of the expert in the analysis itself but also the requirement to prepare evidence for legal proceedings.

The forensic physical evidence categories (for brevity referred to hereafter as forensic fields) that are addressed in this manual are:

- Drugs and precursors
- Fingerprints
- Shoemarks and tyremarks
- Biological material (including DNA and blood pattern analysis)
- Questioned documents
- Firearms and toolmarks
- Fires and explosions
- Fibres, paints, glass and other microtraces
- Digital and multimedia evidence

Considering that all investigation processes start at the scene of crime, staff skill requirements and equipment recommendations for crime scene investigations are also included.

The focus here is restricted to physical evidence from crime scenes. Forensic medical disciplines such as pathology, anthropology, clinical forensic medicine and histology are considered as separate disciplines and are not included in this manual.

UNODC's Laboratory and Scientific Section would welcome observations on the contents and usefulness of the present manual. Comments and suggestions may be addressed to:

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PART I. STAFF SKILL REQUIREMENTS

The most important component of a forensic science facility is its professional scientific staff. In many countries, forensic scientists also appear as expert witnesses in court proceedings and must have the necessary education, knowledge and experience to carry out this responsibility. It is important that staff of forensic laboratories acquire skills not only in specific analytical techniques but also in those related to the forensic science field in which they are working.

Part I of this manual discusses the required skills that the professional scientific staff of a laboratory should possess. It begins with a description of certain general skills that are fundamental to effectively conduct any forensic examination regardless of the type of laboratory, the analyses performed, and the range of physical evidence being examined. This also covers staff skill requirements necessary to investigate physical evidence at crime scenes. The part on general skills is followed by an account of specific staff skill requirements to perform analyses in individual forensic science fields. A brief description of each field introduces each section. The skills related to specific techniques are included in part II.

All required skills are usually gained by a combination of formal education, training and operational (on-the-job) experience. Education from colleges and universities is highly recommended to ensure that forensic personnel have a solid scientific basis with the view to future technological developments and continuous improvement of the laboratory. It is recommended that forensic scientists have a scientific background with tertiary qualifications (BSc and/or MSc, or equivalent). Training is designed to build on the scientific education and provide specific knowledge and abilities directly associated with the work environment. Forensic scientists need both high-level education and relevant training. Adequate training is a matter of priority in situations where forensic personnel lack the desired qualifications. Regarding incoming staff, if training is necessary, it should take place before or at the very beginning of their employment. Finally, experience contributes strongly to the development and capability of a forensic scientist. Obviously, experience is something that can only be gained with time and with competent, comprehensive mentoring.

Forensic scientist vs. law enforcement officer[2]/technician[3]

In general terms, and in order to ensure the quality services required by the criminal justice system, it is recommended that forensic science investigations be performed

[2]A law enforcement officer is an officer with a grade from a national police academy

[3]A technician is a graduate with a diploma from a technical college

by staff with formal scientific qualifications (scientists or law enforcement officers with a scientific background) and not by law enforcement officers that lack this level of education. Despite this desire, there has been a tendency in the past, even in technologically advanced countries, to assign non-scientific law enforcement officers (investigative personnel) with significant forensic responsibilities before the migration to performing procedures in the formal forensic laboratory environment as we know it today. There is now a general trend around the world to employ only scientifically-qualified staff. Exceptions to this include, for example, the fields of digital and multimedia evidence[4] and crime scene investigation. The digital and multimedia evidence discipline, while gradually moving in the same direction, continues to be performed largely by investigative personnel or investigative personnel re-assigned to the forensic laboratory environment. Only recently have advanced education programmes (college majors) and certification programmes emerged specifically for this discipline, as well as the development of external proficiency testing providers. Similarly, law enforcement officers will continue to be involved in certain activities at the crime scene and may, on occasions, be responsible for performing very basic, preliminary forensic analyses.

Similar considerations also apply to the division of work between the scientist and the laboratory technician. It is recognized that only qualified scientists can ensure the necessary oversight of the entire analytical scheme, plan the most appropriate sequence of analyses including contingencies, and provide a conclusive evaluation of the results. Technicians, on the other hand, are trained to use specific analytical techniques to perform individual analyses on given samples.

Even though it is important to cultivate respect for the independence of scientists from police investigations, laboratory staff should be encouraged to establish close collaboration with members of national law enforcement agencies, the legal and judicial community, and vice versa. Good communication and collaboration between law enforcement, the legal and judicial community and forensic scientists is critical to ensure that relevant questions are asked, appropriate samples are submitted for analysis, and the most appropriate analyses are undertaken. This will ensure the best use of all available resources to address the specific questions related to each criminal investigation.

In relation to staff skill requirements, three qualifying terms are used in this manual:

Knowledge	means a theoretical understanding of the scientific approach and the principles behind the analysis itself. It implies an understanding of the underlying theory of the particular analysis/examination (e.g. mechanisms, reactions, limitations, etc.). Knowledge is acquired through a formal and informal learning process.

[4]Also known as forensic information technology and digital imaging.

Ability	means a practical ability to carry out an analysis/examination properly. Ability is acquired through practice.
Awareness	means to be aware of or familiar with a particular issue. It implies the need to know certain information in order to be able to take it into account in a relevant and appropriate manner.

Note that the skills requirements listed for the different forensic disciplines may refer to the collective skills of a team of forensic personnel, i.e. not each staff member will always require all skills listed.

A. General staff skills for forensic personnel, from the crime scene investigation to the laboratory analysis and testifying as an expert in legal proceedings

Under this first general section are included skills related to evidence recognition, detection, protection, recovery, documentation, evaluation and communication. These skills are required for forensic personnel regardless of whether they work at the scene of crime or in a laboratory environment. Such skills are presented first. They are followed by listings of more specific skills for work at the crime scene, and in a forensic science laboratory.

Common skills for work in the forensic science field

- Knowledge of fundamental forensic principles and concepts:
  - Every contact leaves traces (Locard's exchange principle); i.e., it is not possible to come in contact with an environment without changing it in some small way by adding something to it or by taking something away from it (this reflects the concepts of transfer, persistence and relevance).
  - Every object in the universe is, by definition, unique. In situations where the evidence consists of physical markings, made by transfer or deformation, some relevant characteristics of uniqueness in one object may be replicated in another object that has been in contact with the first. Long after the separation of the objects, it may be possible to use such markings to conclude that the objects were in contact at some prior time. Object uniqueness can also be used to demonstrate, or at least approach, individualization or a conclusion of common origin where intrinsic characteristics within the object are not lost or altered by subdivision. With suitable sensitive and reproducible

analytical chemical techniques applied to homogenous objects, similarities seen in the separated parts may serve as a basis for a conclusion of a common source for two items (reflecting the concept of individualization).

– Wherever possible, part of the sample should be saved for further examination, including possible re-examination.
– The need to actively look for significant differences, not just similarities, when comparing and evaluating two items to determine if they could be from the same source.

- Knowledge of principles of ethical conduct necessary for forensic work, including the need for a neutral/objective position, extracting both probative and exculpatory information, and making impartial judgments during the entire investigation (recognition, collection, analysis and evaluation of evidence).
- Awareness of the principles of using tested and validated methodologies, documenting methodologies in standard operating procedures, and remaining an independent finder of scientific results.
- Awareness of sources of bias in scientific procedures and knowledge of techniques to mitigate them.
- Awareness of the limitations of the tools used in the forensic field of expertise, and ability to ensure that they are fit-for-purpose at any one time.
- Awareness of the need for continuing education and training.

Skills required to recognize/detect physical evidence

- Ability to handle evidential material samples of various forms and properties (e.g., liquid, solid, volatile, fragile, toxic, etc.), and carefully observe and record relevant physical characteristics.
- Awareness of the latent nature of many traces in forensic science and of the small amount of material that is typically involved (hence the term “microtraces”).
- Knowledge of optical detection procedures that rely on light theory, including principles related to absorption, reflection and luminescence.
- Ability to distinguish colours, shapes, depth and to observe details (pattern recognition).

Skills required to preserve physical evidence

- Awareness of the transitory and often fragile nature of physical evidence and therefore the requirement to protect evidential items and implement effective preservation procedures.

- Knowledge of how contamination, cross-contamination and loss of evidence can occur.
- Ability to prevent contamination and cross-contamination (e.g., wearing of appropriate protective clothing).
- Ability to implement security measures to protect evidence from being stolen, tampered with, swapped or damaged.

Skills required to document physical evidence and record all aspects of the collection process

- Awareness of the importance of documenting physical evidence using appropriate means (e.g., photography, video, diagrams, case notes, etc.).
- Knowledge of the importance of recording relevant information accurately, legibly and at the time of the examination in order to be able to answer any questions concerning the handling of evidence and the chain of custody (contemporaneous and chronological records must be preserved, unaltered, through to the adjudication of the case).
- Ability to implement measures required to ensure the chain-of-custody, through appropriate packaging, sealing, labelling and documentation procedures.
- Knowledge of photographic principles and equipment (including associated software in the case of digital imaging).
- Knowledge of the strengths and limitations of digital imaging techniques and associated software.
- Ability to use specialized photography in order to document and demonstrate all observations made (for specialized skills related to photography, see part II, section *(l)*, page 69).
- Awareness of the need to preserve the form of the original digital image file even after making copies of it (i.e., if compression or enhancement operations are necessary, these operations are carried out on copies).

Skills required to recover, package, transport, and store physical evidence

- Knowledge of the principles of sampling to ensure that samples, representing the total amount of evidence, are collected, taking into account the physical state of the suspected material and the substrate bearing the evidence.
- Ability to use available collection techniques and equipment in accordance with the nature of the evidence.
- Ability to use appropriate storage conditions for evidence in order to avoid contamination, cross-contamination, degradation, and loss of evidence during transport or storage.

- Ability to recover and examine one type of evidence and still preserve the best chance to examine or analyse other types of physical evidence that may be present on the same item.

Skills required to evaluate scientific findings in the context of the case

- Knowledge of the forensic comparison process and the particular details most appropriate for each evidence type, as well as the ability to compare evidential material (e.g., collected at the crime scene) with reference material (whose provenance is known, including from a database).
- Ability to actively propose and test alternative hypotheses that could provide exculpatory information as well as testing the primary hypothesis proposed by the submitting agency, or others proposed by investigators and scientists during the course of the investigation.
- Awareness that initially evidential items must be analysed and interpreted independently from reference items, and the relevant characteristics documented prior to commencing the comparison phase (this relates to the fundamental principle that the forensic scientist should never actively look for characteristics found in the reference item in the evidential item as, quite the opposite, the forensic scientist should actively seek differences between the items being compared; refer to the "exclusion principle" above).
- Awareness of background levels of various materials (e.g. hairs, fibres, glass), how such materials need to be taken into consideration when interpreting trace evidence, and an ability to take this information into account when evaluating the findings.

Skills required to communicate scientific findings

- Knowledge of the type, extent and purpose of the forensic scientist's report.
- Ability to interpret and communicate scientific results in an appropriate format for the client (often lay persons), in the form of an expert's report containing technical and scientific findings (in particular, there is a need for a clear and complete report that communicates the nature of the physical evidence, the results and conclusions of all tests performed, and any specific limitations in relation to these examinations).
- Awareness of the role of the other participants in the investigation (prosecutors, investigators, criminal intelligence analysts, etc.) and the way in which advice should be communicated according to the needs of the end user.
- Ability to manage customer expectations relating to the realistic results that can be obtained through forensic analysis.
- Ability to prepare and disseminate documents such as reports.

- Ability to conduct data analyses as appropriate, and to protect the security and integrity of computer data.
- Ability to synthesize a conclusion incorporating multiple test results in a logically consistent matter.
- Ability to testify as an expert in front of the court, expressing technical details in a manner that is clear and understandable by all players, including the jury.

Specific skills required for work at the crime scene

- Knowledge of legal and organizational requirements.
- Knowledge of how to ensure the scene is protected adequately.
- Knowledge of basic quality assurance principles, e.g., documentation, traceability, documented procedures.
- Ability to have a thoughtful, critical and flexible approach.
- Knowledge of contemporary techniques for locating and preserving physical evidence.
- Ability to formulate a systematic but adaptable plan before starting the scene processing.
- Ability to evaluate the crime scene in light of the case's context to facilitate the recognition of relevant physical evidence.
- Ability to proceed calmly without preconceived ideas and premature conclusions.
- Ability to work in a team with, for example, police officers, medical examiners, prosecutors, etc.
- Ability to implement safe working practices at the scene, including handling procedures for unknown, potentially hazardous chemicals and biological agents.
- Ability to document and record the integrity of the scene.
- Awareness of the scope of current laboratory capabilities in order to look for, detect and collect relevant evidence at the scene to be later submitted to the laboratory for analysis.
- Ability to recognize, detect, collect and package, following approved protocols, all forms of biological evidence at the scene.
- Knowledge of procedure to give/send a request for analysis or examination of items at a forensic laboratory and the ability to use it.

Note: Skills required for specific types of crime scenes are included in the corresponding sections below (e.g., for skills for fire and explosion investigations, see part I, section *(f)*).

Specific skills required for work in the laboratory (good laboratory practices)

- Ability to have a critical approach (especially when interpreting evidence).
- Ability to formulate a laboratory examination strategy, e.g. sequence of required tests.
- Knowledge of legal and organizational requirements.
- Knowledge of basic quality control and quality assurance principles, including participation in external quality assurance processes such as proficiency tests.
- Knowledge of the importance of combining test results from complementary analyses to strengthen laboratory findings.
- Knowledge of the limitations of any tests used and the importance of clearly documenting these limitations in case files and reports.
- Knowledge of scientific and technical literature in the forensic science (and related scientific) field(s) of interest and an ability to remain up-to-date with respect to this knowledge.
- Ability to implement safe working practices in the laboratory with respect to handling unknown, potentially hazardous chemical and biological evidence.
- Knowledge of the capabilities and limitations of personal physical barriers, such as gloves, laboratory coats, and safety goggles, that are used both to protect the analyst from the evidence and reagents, and the evidence from the analyst.
- Knowledge of safety procedures with respect to handling compressed gases, flammable, toxic and corrosive substances, bio-hazardous materials, high-intensity light sources (including UV lamps and lasers), etc.
- Ability to prepare reagents and solutions.
- Ability to accurately weigh samples, including knowledge of the associated error (measurement uncertainty).
- Ability to handle very small/microscopic/latent physical evidence.
- Ability in the operation, care and maintenance of equipment, including proper use, troubleshooting, testing, calibration, cleaning, routine maintenance and emergency procedures.
- Awareness of destructive versus non-destructive methods, and therefore an ability to carry out examinations in an order that maximizes the information and minimizes evidence loss (i.e. examination sequences always start with non-destructive examinations and end with destructive methods where necessary).
- Awareness of the difference between presumptive and confirmatory tests and the need for confirmatory tests to be applied where possible.

- Ability to apply sample preparation techniques appropriate for the type of physical evidence under examination, including knowledge of extraction techniques and associated theory.
- Knowledge of basic statistical methods and their capabilities and limitations, and an ability to apply appropriate statistical methods where necessary.

B. Specific staff skill requirements in different forensic fields

Under this section are included the specific skills required to work in the different forensic fields. Skills related to the use of (analytical) techniques are included in part II. Note also that the skill requirements listed for the different forensic fields may refer to the collective skills of a team of forensic personnel, i.e. not each staff will always require all skills listed.

(a) Biological material (including DNA)

When encountering a body fluid stain, one of the first tasks is to determine the type of fluid present (e.g., blood, saliva, semen). If blood is present, determination of the species from which the blood originates is also important. Finally, if human blood is confirmed (or another human body fluid is present), DNA analysis is performed and the results either include or exclude a suspect as possible source of a stain (potential for inference of individualization). Statistics based on population genetics provide a tool to determine the strength of the evidence.

In addition, the analysis of the pattern, size and location of bloodstains at crime scenes provides relevant information about the dynamic of the crime, and can assist in reconstructing the event. The bloodstain analyst needs to consider the probative value of the bloodstain evidence against the evidentiary potential of other physical evidence within a scene on a case-by-case basis. For example, a bloodshed event near a wall may have stains suitable for manual "stringing" to determine the area of origin of the stains. However, the same wall may also have latent fingerprint evidence that could be damaged as a result of the "stringing" process. Liaison with other specialists within the scene prior to processing is essential.

Level of education recommended

BSc or MSc in biology, bio-chemistry, molecular biology, chemistry.

Skills required for detection of biological material and DNA analysis

- Knowledge of the different types of physical evidence that can potentially be typed for DNA.

- Awareness of the sensitivity of DNA analyses and the importance of respecting strict anti-contamination measures (including an awareness of the various sources of contamination and the recommended measure to prevent contamination).
- Ability to implement protective measures against potential dangers associated with biological material.
- Awareness of the potential and pitfalls of preliminary tests for screening stains prior to collection and full laboratory analysis and a full knowledge of when their use is not appropriate.
- Knowledge of detection, collection and packaging protocols for biological evidence in the laboratory.
- Ability to implement the best strategy to adopt when examining suspect and reference material to avoid cross-contamination.
- Awareness of how documentation of errors, including contamination, in a central log can assist in troubleshooting.
- Knowledge of the appropriate storage of body fluids, biological specimens and dried biological stains.
- Awareness of the potential conflicts or trade-off between: *(a)* presumptive/screening tests for physiological fluids and DNA analysis, *(b)* fingerprint detection and enhancement techniques and DNA analysis.
- Awareness of other evidentiary factors when sampling DNA, such as the need to document the morphology of a stains prior to sampling in order to preserve information on how that particular stain was deposited.
- Knowledge of the various DNA analysis methods and their respective capabilities, limitations, value and application (e.g. autosomal STR, Y-STR, mitochondrial sequencing).

Skills required for the evaluation of DNA profiles

- Knowledge of the various artefacts that can be observed in a DNA profile, e.g., stutters and allelic drop-outs that can create anomalies in the profile (i.e. alleles present which do not exist in the original sample or absent which exist in the original sample).
- Ability to properly interpret and compare DNA profiles.
- Ability to properly estimate the strength of the evidence using appropriate statistical tools (e.g. population frequencies, Bayesian approach).
- Knowledge of population genetic factors such as substructure and relatedness.

- Knowledge of the differences between and uses for various databases (e.g. population, felon, missing person): capabilities and risks involved when searching the various databases.
- Knowledge of the potential for intelligence and criminal analysis by trace to trace comparisons and/or partial profiles.

Skills required for blood pattern analysis

- Knowledge of the history, development and advancement of bloodstain pattern analysis.
- Knowledge of the underpinning biology, mathematics, and physics related to bloodstain pattern analysis.
- Knowledge of the inherent limitations of bloodstain pattern analysis.
- Awareness of appropriate protective (OH&S) measures in a bloodstained scene.
- Ability to recognise key bloodstain patterns and understand the mechanism(s) by which they are created.
- Ability to discuss and apply appropriate bloodstain pattern sample selection criteria and determine impact angles for those bloodstains.
- Ability to determine a probable area of convergence (two dimensional) and area of origin (three dimensional) for a given bloodshed event.
- Ability to comprehensively record bloodshed events.
- Ability to evaluate a bloodstain scene.
- Ability to appropriately document, report, and communicate an analysis of a bloodshed event in a court or inquiry environment.

General skill requirement

- Knowledge of the principles and ability to carry out relevant techniques to analyse biological material (including DNA). For suitable technique in this field see table in annex 1.

(b) Digital and multimedia evidence

The digital and multimedia evidence (DME) discipline is the most recently recognized forensic science discipline in the forensic science community. DME can be divided into the following sub-disciplines:

Computer forensics, or forensic information technology

(i.e. the analysis, for legal matters, of computers, cellular telephones, personal data assistants, and other devices that store data digitally)

Computer forensics is the recovery, preservation, imaging, extraction, analysis, verification, and reporting of forensic processes of computers, servers, networks, mobile telephones, and other digital devices. Generally, the majority of the computer forensic analysis will be conducted using a "dead" acquisition method, that is a system that is shut down and data extracted using forensic tools and software. However, there is a growing requirement for digital data acquisition from operating (live) systems to identify running (volatile) processes and to defeat active disk encryption capabilities, and identify potential malicious content/code operating on a system that has been penetrated or compromised. Accessing live systems may result in the forensic process changing original data by adding a small amount of code to the original computer, but seeks to avoid changing original user data which may have probative or investigative value.

Many of the fundamental procedures performed in computer forensics are applicable to forensic audio and video analysis as well, particularly when the recordings are made with a computer or other digital devices. The examination of digital media is generally a four step process; first the original digital device is imaged, then that image is verified as accurate. Thirdly, the data analysis is conducted on the imaged copy, and finally the results are reported and archived.

It is during the third, technical analysis stage for each sub-discipline that discipline-specific knowledge and abilities diverge and where specific competencies unique to the sub-disciplines can be identified. It is noted, however, that not every case is the same and processes may deviate depending upon the unique circumstances encountered.

Forensic audio analysis

(i.e. the analysis, for legal matters, of audio recordings)

Forensic audio analysis includes the recovery, preservation, extraction, examination/analysis, enhancement, authentication, comparison and duplication of audio recordings and associated metadata in legal matters. It involves the restoration of damaged tapes and digital recordings, application of filtering and noise reduction techniques to enhance audio output, recording authentication, sound sequencing and identification, and voice identification.[5] A forensic audio examiner will employ the use of a variety of hardware and software to perform analysis of audio recordings and to protect the integrity of the original recording

[5]A subject matter expert should be consulted as speaker comparison and voice identification go beyond the technical aspects of forensic audio analysis.

The audio laboratory will require specialized construction to protect it from externally generated noise that can interfere with audio examination processes. The equipment for the laboratory shall be of broadcast or professional grade along with high quality cables, connectors and output media (tape, CD, DVD). The use of tools to perform data recovery, enhancement, analysis and output are of professional grade, and are generally available through commercial proprietary software and hardware vendors.

Forensic video analysis

(i.e. the analysis, for legal matters, of video recordings)

Forensic video analysis is the recovery, extraction, examination/analysis, enhancement, authentication, comparison, evaluation and extraction of video (and associated metadata) including digital media, tape, film, optical media, and other storage devices capturing video in legal matters.

Image analysis, which includes the content analysis of images for authenticity and characteristic identification, may also be considered within the realm of DME. It can be a separate sub-classification of computer forensics, video analysis, or may warrant its own designated forensic discipline. Regardless of the classification, these forensic services have a high degree of overlap relative to the forensic processes of preserving and analyzing digital devices.

Level of education recommended

Degree in information technology, computer science, maths, science, electrical engineering, or a four-year college degree in another discipline with technical training and experience in computer hardware and software.

Common skills required in the digital and multimedia evidence disciplines

- Knowledge of computer workstation hardware, configuration, software and connection of peripheral storage devices.
- Knowledge of basic electronics as it applies to the safe operation and examination of digital media.
- Knowledge of digital storage media characteristics and specifications.
- Understanding of physical handling and storage procedures in the laboratory to reduce the risk of changing or altering the seized data.
- Understanding of the need to secure derivative evidence (data recovered which may contain contraband, i.e. child pornography).
- Ability to maintain equipment and perform basic maintenance functions.

- Ability to identify the limitations of the tools used in DME disciplines and ensure that they are fit-for-purpose at any one time.
- Ability to disassemble and reassemble digital hardware storage devices and computers.
- Ability to identify and document damage to storage media or equipment under examination.
- Ability to draft clear reports in non-technical terms that addresses the requested services.
- Ability to provide guidance to investigators regarding the value of digital evidence, evidence preservation, packaging, transport, storage, and to manage expectations of the analytical output.

Common skills required for DME investigations at the crime scene

(For skills related to general crime scene examination, see part I, section A, page 7)

- Ability to identify digital and multimedia storage devices at a crime scene and to properly secure, preserve and seize the evidence.
- Knowledge of how digital and multimedia storage devices can be booby trapped; the biological hazards (blood, drug chemicals, etc.) they can contain and the special handling required in these cases.

Specific skills required for computer forensics

- Knowledge to recognize non-traditional operating systems and proprietary software applications, password protected files, and encryption.
- Knowledge of how data is stored on various media types and deleted data recovery techniques.
- Knowledge of the concepts for hiding data (steganography).
- Ability to examine and interpret computer forensic artefacts (Internet history, temporary internet files, email, etc.) to provide a timeline analysis of events that occurred on a computer or other digital device under examination.
- Ability to analyse advanced or non-traditional computer operating systems or proprietary software applications.
- Ability to analyse unique digital devices such as global positioning systems or entertainment systems.
- Ability to extract data from a live computer or network using advanced forensic extraction tools and methodologies.

Specific skills required for forensic audio analysis

- Knowledge of audio recording devices and media (analog and digital), digital device hardware.
- Knowledge of audio recording, streaming, storage and compression formats (CODECs).
- Knowledge of audio recording architecture to determine the best approach for seizing the data and conducting an analysis.
- Knowledge of acoustic concepts to include physical acoustics (sound propagation, environmental and material influences) and psychoacoustics (speech production, hearing and perception).
- Knowledge of mathematics and signal processing concepts to include sampling, quantization, filtering, spectral estimation and sound level representations.
- Knowledge of electrical, magnetic, and signal analysis techniques, their limitations, sources of error and how to apply them to recording systems, physical media, logical signal formats, and sampled signals.
- Awareness of critical listening skills and the ability to identify frequency response, harmonics, stereo fields, phasing, noise components, signal degradation causes and compression effects.
- Ability to identify audio recording systems and devices at a crime scene and to properly secure the audio recording evidence in its native format.

Specific skills required for forensic video analysis

- Knowledge of video recording devices and media (analog and digital), digital device hardware.
- Knowledge of video and image recording, streaming, storage and compression formats.
- Knowledge of video recording architecture to determine the best approach for seizing the data and conducting an analysis.
- Knowledge of imaging concepts to include physical imaging (light propagation, frequency and colour, photography, sensor design and operation) and perception (human vision physiology, perception of shape, colour, and special frequency).
- Knowledge of mathematics and signal processing concepts to include sampling, quantization, filtering, spectral estimation, intensity and colour representations.
- Knowledge of print processes and the ability to maintain optimal image quality throughout an imaging system from capture to print.

- Knowledge of optical, electrical, magnetic, and signal analysis techniques, their limitations and sources of error, how to apply them to imaging systems, physical media, logical imaging and video formats, and sampled signals.
- Ability to identify video recording systems and devices at a crime scene and to properly secure the video recording evidence in its native or proprietary format.

General skill requirement

Knowledge of the principles and ability to carry out techniques relevant to computer forensics, forensic audio analysis and forensic video analysis, respectively. For appropriate techniques in these fields, see the table in annex 1.

(c) Drugs and precursors

This section covers drugs and precursors in seized materials as well as drugs (excluding alcohol) and their metabolites in biological specimens (i.e. toxicology). Depending on the purpose of the analysis and the technique used, various types of information are obtainable, including presumptive identification, confirmatory identification, quantitation, and physical/chemical profiling. While techniques for the analysis of various drugs and precursors are very similar, sample preparation methods need to be adapted to the particular sample type. When analysing drugs in biological matrices, sample preparation may be even more complex and further analytical techniques are generally required to attain a high level of sensitivity.

Level of education recommended

BSc or MSc with major in chemistry (or equivalent).

Drug and precursor analyses in seized materials

- Knowledge of the most common drugs of abuse encountered on the illicit market including their production or synthesis, consumption, effects and key precursors.
- Awareness of the crucial need for reference samples for comparison purposes and an ability to prepare, if necessary, secondary standards.
- Ability to apply sampling procedures (using a statistical approach when required).
- Awareness of the presence of other evidence on drug packaging (e.g., fingerprints, hairs, fibres, DNA, toolmarks) and an ability to preserve such evidence.
- Awareness of the evidential value of the packaging itself (e.g. type of plastic packaging material, adhesive tape, etc.).

Drug analyses in biological specimens

- Knowledge of major metabolites, characteristics of different biological matrices, and suitable extraction techniques for biological specimens.

- Ability to implement appropriate preventive measure with respect to health and safety, especially in handling biological specimens.

General skill requirement

Knowledge of the principles and ability to carry out techniques relevant to the analysis of drugs and precursors in seized material and/or biological specimens. For appropriate techniques in this field, see table in annex 1.

(d) Fibres, paints, glass and other microtraces

Fibres (including hairs), paint and glass, also called trace evidence (or “microtraces”), can be transferred between individuals and objects during the commission of a crime. Although in most cases trace evidence cannot by itself positively associate a suspect to a specific activity, laboratory examinations may narrow the identification of the source of such evidence and the type of activity that resulted in the transfer of material. Other microtraces include, for example, soil, metal particles and pollen.

Level of education recommended

BSc or MSc with a major in chemistry.

Skills required for the examination of fibres, paints, glass and other microtraces

- Knowledge of the methods of mass production of the micro traces of interest, the composition of these materials, and the various classification schemes for each of them (e.g., natural/synthetic fibres, automotive/architecture paint, float and container glass, etc.).

- Knowledge of soil, botanical identification of plant fragments, pollens, spores, etc.

- Ability to adapt the search and collection methods to the different categories of micro traces (e.g., application of 1:1 taping procedures where relevant and justified).

- Knowledge of transfer and persistence phenomena for such trace evidence.

- Knowledge of the uniqueness of a physical fit, especially relevant for glass and paint evidence.

- Ability to determine the direction of impact for a fractured glass pane.

- Ability to select a subsample of fibres (or paint, glass) that is representative of the whole sample/group.
- Ability to properly evaluate/interpret matching characteristics using frequencies of occurrence for these characteristics and transfer/persistence probabilities, as well as an ability to assess the probability that the microtrace in question was present before the action under investigation actually took place.

General skill requirement

Knowledge of the principles and ability to carry out techniques relevant to the analysis of fibres/hairs, paint, glass and other microtraces. For appropriate techniques in this field, see the table in annex 1.

(e) Fingerprints

This section covers fingerprints but is equally applicable to other ridge skin impressions and other body contact patterns (e.g. bare foot and ear). Such marks can be visible or latent. Visible marks can be positive (addition of material/dust), negative (removal of material/dust) or indented. Latent marks require the application of an optical (e.g., UV), physical (e.g., powdering) and/ or chemical treatment (e.g., ninhydrin) for visualization. Latent fingerprints deposited by the ridges of the finger are generally complex with respect to their chemical composition, consisting of natural secretions (e.g. of eccrine and sebaceous origin) and contaminants picked up from the environment.

Level of education recommended

BSc or MSc with chemistry and biology components.

Skills required for the detection and recording of latent marks

- Knowledge of the mechanism of the various detection methods (optical, physical, chemical) and their applicability depending on the substrate (i.e., porous, semi-porous, non-porous surfaces) and the environmental conditions (e.g., whether the fingerprints have been exposed to high humidity or have been wet).
- Knowledge of the chemical composition of latent marks (i.e., natural secretions) and possible contaminants (e.g., paint, blood).
- Knowledge of the basic physics and chemistry applied to fingerprint detection and enhancement techniques, including light, colour and photoluminescence theory.
- Awareness of the need for detection techniques that preserve the delicate ridge patterns required for identification purposes.

- Awareness of the general detection methodology and the sequence of examinations (e.g., non-destructive to destructive methods), and the importance of recording results after each stage of a development sequence.
- Awareness of advanced techniques to detect and enhance fingerprints on “difficult” substrates and for aged or degraded deposits.
- Ability to record high-resolution images suitable for identification purposes (e.g., in 1:1 (real size) as required by most fingerprint identification services).

Skills required for the comparison of recorded marks

- Knowledge of general fingerprint patterns: loop, whorl, arch.
- Knowledge of the individualization power of fingerprints (and other marks such as bare foot and ear marks) and the origin of their unique characteristics (for fingerprints, known as ridge characteristics or minutiae).
- Ability to establish appropriate standards for earmarks and associated comparison material, including a knowledge of the importance of using various conditions (e.g., high/low pressure, standing up) and the high intra-variability of the marks produced.
- Knowledge of contemporary identification methodologies, such as: analysis of ridge patterns and types of minutiae; comparison of patterns and details; evaluation of the contribution of each component to the overall identification; and, verification by an independent examiner (ACE-V methodology).
- Ability to observe relevant details (pattern recognition).
- Awareness of the different standards related to the process of identification of a source and knowledge of statistical approaches to evaluate comparison results.
- Awareness of the value and ability to use mark-to-mark comparisons for intelligence and crime analysis purposes.
- Awareness of the advantages and risks involved when using databases of evidential marks and reference prints.

General skill requirement

Knowledge of the principles and ability to carry out relevant detection and enhancement techniques for fingerprints and other skin impressions (including bare foot and earmarks). For appropriate techniques in this field, see the table in annex 1.

(f) Fire and explosion

A fire is a rapid, persistent chemical change that releases heat and light and is accompanied by flame, especially the exothermic oxidation of a combustible substance. An explosion is a fast and violent release of mechanical, chemical or nuclear energy with the generation of high temperature and usually gases. The investigation of such cases aims at determining the origin and cause of the fire or explosion. Specifically, this includes the analysis of relevant samples collected at the scene, reconstruction of the events (based on damage observed at the scene), and the detection and identification of accelerants, also called flammable liquids, or detonating/deflagrating materials (explosives).

Level of education recommended

BSc or MSc with major in chemistry

Skills required for fire and explosion scene investigation

(For skills related to general crime scene investigation, see part I, section A, page 7)

- Ability to undertake an extensive on-site investigation for both fires and explosions, in order to determine origin and cause.
- Knowledge of the chemistry and physics of combustion (e.g., necessary presence of ignition source, oxygen, combustible material) and explosion processes.
- Ability to correctly interpret burn patterns and blast effects (e.g., multiple origins, heat/ignition sources, ventilation sources, flammable/explosive products) and to determine accidental versus deliberate causes.
- Ability to properly locate, collect, package and store physical evidence and substrate controls (e.g., specific bags/containers to prevent loss of volatile compounds).
- Ability to correctly report on fire and explosion phenomena (including determination of cause and origin) based on the scene investigation.

Skills required for the laboratory analysis of fire debris and explosives

- Knowledge of the broad range of accelerants that may be used to initiate and accelerate a fire.
- Knowledge of the common pyrolysis products from substrate materials (e.g. plastic, carpet) and an ability to differentiate them from extraneous fire accelerants.
- Knowledge of the various types of explosives, their physical and chemical properties, and the damages that they can produce.

- Ability to correctly report on fire and explosion phenomena (including determination of cause and origin) based on the laboratory analyses conducted on scene samples.

General skill requirement

Knowledge of the principles and ability to carry out techniques relevant to fire and explosion investigations. For appropriate technique in this field, see the table in annex 1.

(g) Firearms and toolmarks[6]

The forensic field "firearms and toolmarks" extends beyond comparison of bullets and cartridge cases to include knowledge of operation of all types of weapons, restoration of obliterated serial numbers on weapons, detection and characterization of gunshot residues (GSR), estimation of the muzzle-to-target distances, detection of primer residues on hands and reconstruction of shooting trajectories.

A toolmark is any impression, cut, gouge or abrasion caused by a tool coming into contact with another, generally softer, object. Bullet and cartridge case markings are a subset of toolmarks. Manufacturing characteristics of tools, including components of firearms that function as tools in the marking of ammunition components, are called class characteristics. When present on a surface, bullet or cartridge case they provide information on the type of tool at the source of the mark. Individual patterns of acquired characteristics, also called accidental characteristics or striations, can be used during the comparison process to individualize the source of the trace.

Level of education recommended for GSR analysis

BSc or MSc in chemistry.

Level of education recommended for toolmarks and ammunition components examination

BSc or MSc with physics or chemistry education components, including probability and statistics.

Skills required for GSR analysis

- Ability to use firearms to produce the comparison firing tests/standards (this activity requires a shooting gallery or special range, water tank and security/protective rooms).

[6] Including gunshot residues (GSR), ammunition components, toolmarks, serial number restoration

- Awareness of the consequences of shooting: *(a)* traces on the firearm, *(b)* traces on bullets and cartridge cases, *(c)* traces on shooter's hands, *(d)* traces on the target/victim.

Skills required to conduct examinations of toolmarks and ammunition components

- Knowledge of the various characteristics of traces on bullets and cartridges (i.e., manufacturing characteristics, also called class characteristics, and acquired characteristics, also called individual characteristics) and the information provided by each of them.
- Knowledge of the identification and individualization process and methodologies used: starting by comparing manufacturing characteristics and then acquired characteristics.
- Ability to identify the type of firearms/tool at the source of the evidence based on the manufacturing characteristics.
- Ability to establish comparison tests firing/establishment of standards, taking into consideration the influence of the metal of the bullet (intra-variability).
- Ability to establish standards for tool marks, including the proper choice of the substrate.
- Ability to compare bullets, cartridges and toolmarks using acquired characteristics.
- Awareness of the temporary nature of acquired characteristics (e.g., over time and use new accidental characteristics can be acquired and old can be erased).
- Ability to properly evaluate concordances and discordances, using a statistical approach to evaluate the significance of matching striations.

General skill requirements for firearms and toolmarks examinations

- Knowledge of firearms security rules and ability to safely handle/manipulate firearms.
- Knowledge of the different types of firearms and the determination of their operability, their manufacture characteristics (e.g., striations inside), the shooting process (details of what takes place during the shooting for the firearm, the bullet, the cartridge and the gun shot residues).
- Knowledge of the various types of ammunition, propellant (powder) composition and bullet composition and their influence on subsequent investigations.

Knowledge of the principles and ability to carry out relevant techniques on ammunition components, tool marks, serial number restoration and GSR. For suitable techniques in this field see the table in annex 1.

(h) Questioned documents[7]

A questioned document relates to any object, excluding computer or digital device, that contains written or recorded information whose content, source or authenticity is in doubt or questioned (e.g., forged contracts, identity documents, passports). Documents examination in this manual refer to ink and paper analyses and examinations to determine authenticity of a document and to examination of technical typewriting and printing produced by office machines to determine the typestyle and the machine at the origin of the written information. The act of writing implies a learning process and an adaptation to fit the needs and the ability of the writer which leads to the potential of identifying the author of handwritten texts or signatures. Document examiners compare unidentified documents with a known sample ("standard").

Level of education recommended

BSc or MSc with some chemistry education components.

Skills required for document examinations

- Ability to properly collect and store documents (e.g., do not write on an envelope with a document inside).
- Knowledge of the various substrate types (e.g. paper, polymers) and the main features useful for characterizing them.
- Knowledge of the different security features (e.g., watermarks, fluorescent fibres) existing in official documents (e.g., banknotes, identity documents).
- Knowledge of the characteristics of different sort of pens (e.g., ballpoint, gel pen), properties and composition of inks (e.g., pigments, dyes), manufacture and distinguish features of paper (e.g., watermarks, recycled, vellum).
- Knowledge of the influence of environmental factors on inks characteristics (e.g., sun, humidity).
- Knowledge of the type face characteristics present on typewritten information (manufacture characteristics and acquired characteristics).
- Knowledge of the different printing methods and devices (e.g., offset, intaglio, inkjet) and ability to identify on documents the printing characteristics produced by these methods.
- Knowledge of the different kinds of fake documents: forgery (add/delete item on an existing document) and counterfeit (create a whole fake document).

[7] Detailed information about forensic examination of documents, including staff skills requirements, is provided in the *Guide for the development of forensic document examination capacity*, United Nations New York, UNODC (2010), ST/NAR/42.

Skills required for handwriting examinations

- Ability to determine the characteristic formations of letters/words and depict individual writing characteristics in handwriting.
- Knowledge of the various options to forge handwriting.
- Ability to observe details (pattern recognition).
- Ability to distinguish genuine handwriting from forgeries.
- Ability to collect control handwriting samples suitable for comparison with the questioned handwriting.
- Awareness of the various interfering factors of handwriting (e.g., position of the writer, disease, physical condition, influence of alcohol, writing surface and writing instrument).
- Ability to compare individual characteristics in the questioned handwriting with known handwriting specimens.
- Ability to properly evaluate concordances and discordances in handwriting comparison and assess the value of the characteristics.

General skill requirement:

- Knowledge of the principles and ability to carry out relevant techniques for the investigations involving questioned documents. For suitable techniques in this field, see the table in annex 1.

(i) Shoemarks and tyremarks

Shoemarks or other footwear outsole marks are traces coming from the outsole of a shoe or of another footwear outsole. These can be in 2D (positive, addition of material/dust, or negative, removal of material/dust) or 3D. Tyre marks are the consequence of transit (3D) or braking (2D). Manufacturing characteristics, also called class characteristics, give information about a shoe or car (e.g., brand, model). Individual patterns of acquired characteristics, also called accidental characteristics, can be used during the comparison process to individualize the source of a shoemark, other footwear outsole mark or tyremark.

Level of education recommended

BSc or MSc

Skills required for the visualization of latent marks in order to collect them

- Knowledge of the type of traces: 2D positive/negative and 3D and the various methodologies to detect, document and collect traces.

- Knowledge of the different levels of characteristics on shoes and tyres (e.g., manufacturing characteristics, e.g., size, shape; and acquired characteristics, e.g., cut, gouges).
- Knowledge of the different types of illumination needed to observe and photograph shoe and tyremarks in an optimal way (forensic lights, angles of illumination, method of photography).

Skills required for the comparison process of recorded marks

- Knowledge of identification and individualization process methodology: starting by comparing manufacturing characteristics and then acquired characteristics.
- Awareness of the temporary nature of acquired characteristics (e.g., over time and use new accidental characteristics can be acquired and old can be erased).
- Ability to observe details (pattern recognition).
- Ability to exclude common source due to inexplicable discordances.
- Ability to use trace to trace comparison for intelligence and crime analysis.
- Ability to use statistical information to evaluate concordances, e.g., frequency of characteristics.

General skill requirement

- Knowledge of the principles and ability to carry out relevant detection and enhancement techniques for shoemarks and tyremarks. For suitable techniques in this field, see the table in annex 1.

PART II: EQUIPMENT RECOMMENDATIONS

Part II of this manual discusses equipment, materials and accessories related to different techniques commonly used in forensic science. Not all items will be needed in every laboratory and, in some cases, additional items may be needed because of unusual conditions or for specific incidents. Moreover, in some countries, air-conditioners, dehumidifiers and voltage and water-pressure regulators should be considered as being essential. In order to ensure adequate and fit-for-purpose forensic science services, careful needs assessments are required. These should include the purpose of the analysis, the caseload and the characteristics of the techniques.[8]

National or regional authorities planning to establish or to strengthen forensic capacities and laboratories may wish to consider:

1. The recommendations made in this manual on the equipment requirements for a minimum service in each forensic science field (part II, section A below). When further developing a laboratory beyond minimum services and/or upgrading an existing laboratory, annex 1 may be consulted for an overview of the various techniques and their fields of application in forensic casework. However, a careful decision has to be made as not all techniques mentioned in annex 1 are necessary for an adequately equipped laboratory.

2. The recommendations made in this manual on the equipment requirements for the different techniques (part II, section B below). This section begins with the equipment necessary to process crime scenes, followed by a list of general laboratory equipment common to laboratories providing services across a wide range of forensic science fields.[9] Equipment requirements for specific techniques are then presented. The lists given should be considered as starting point and be adapted to each laboratory situation. Each section is complemented by the skills required for the proper use of the equipment.

[8] Guidance to assess forensic services and infrastructure, including both crime scene investigations as well as forensic laboratory operations, is available in the module on "Forensic Services and Infrastructure" of UNODC's Criminal Justice Assessment Toolkit; accessible at: www.unodc.org/unodc/en/scientists/criminal-justice-assessment-toolkit.html.

[9] Not all the general equipment may be necessary when establishing or upgrading a laboratory providing specific services (e.g., to investigate economic crimes).

Relatively expensive equipment and consumables that have to be regularly purchased are marked with * and with ¤, respectively, in the lists below. Annex 2 provides additional guidance in the form of a classification of the various techniques, based on the initial purchase and running costs (including consumables), the infrastructure requirements (facility, special requirements such as air conditioning, stable electrical supply, etc.), the complexity of operating the related equipment (how complex it is to perform the analysis in order to get reliable results, including troubleshooting and maintenance activities), and the skills required for meaningful interpretation of the results (considers the degree of freedom that the technique leaves to the analyst when evaluating the results, assuming that the analyst is knowledgeable about the limitations of the technique).

In any event, it is recommended that Governments considering the acquisition of expensive equipment review all national resources to determine whether these items and the related skills are already available in another local facility.

National authorities should, after having decided that additional equipment is required, pay special attention to such matters as purchasing (including competitive bidding and tender procedures), after-sales services, service contracts, warranty requirements, compatibility with existing equipment, trained personnel and/or training facilities, and the availability of operating and maintenance manuals in local languages. It is critical to ensure the availability of ongoing financial allocations sufficient for repair, maintenance of equipment and purchase of consumables. As an estimate, laboratory instrumentation should be considered on a ten-year replacement cycle. Therefore, the annual budget should include approximately 10 per cent of the start-up costs each year in order to attain the replacement funds at the end of the suggested 10-year cycle, with rollover of accrued funds into each following financial year if not spent.

Legend:	*	These instruments, although desirable, are relatively expensive
	¤	Consumables that have to be regularly purchased

A. Minimum equipment requirements for selected forensic science fields

This first section presents the basic, minimum equipment recommended for commencing casework in an individual forensic science field. For each field, the entire list of techniques is compulsory. Without all the listed equipment, it is not recommended to start in this field due to the risk of not obtaining all the required information.

In addition, the availability of staff with the skills relevant to the specific forensic field (outlined in the respective section of part I of the manual) is a prerequisite.

(a) Crime scene investigation

In order to properly process a crime scene, the following equipment is considered to be the minimum requirement. Equipment is required that relates to:

- Protection and safety at the scene
- Evidence detection (incl. high intensity, variable wavelength and oblique light source), collection and documentation (incl. photographic equipment)
- Powdering techniques for fingerprints and other suitable marks
- Lifting techniques for 2D shoemarks
- Casting techniques for 3D marks (shoes, tyres, toolmarks, fingerprints)
- Toolkit

For detailed information, see part II, section A, crime scene investigation, on page 33.

Note: Specific equipment may be required for particular incident scenes (e.g., clandestine drug laboratories, fire and explosion scenes).

(b) Drugs and precursors

Identification of illicit drugs and the identification of seized material are considered as a minimum service. (Note: toxicology is not considered as a minimum service but an additional service, to be included as part of a later laboratory upgrading phase). To achieve this, the minimum is to implement the following techniques:

- Optical examination
- Photography (general)
- Spot tests (for presumptive identification)
- Stereomicroscopy
- Brightfield microscopy (for cannabis identification)
- Sample preparation techniques for drugs and precursors (extraction/separation and distillation/evaporation)
- Thin layer chromatography (for identification and semi-quantitation)
- Optional: microcrystal tests (for identification)

(c) Fingerprints

Visualization of latent prints, and the comparison and search processes aimed at individualizing fingerprints/attributing the fingerprint to a certain person are considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized)
- Preparation of inked exemplars
- Powdering (for non-porous surfaces, both on-site and in the laboratory)
- Ninhydrin (for porous surfaces)
- Hard-copy fingerprint database (inked 10-print collection)

(d) Shoemarks and tyremarks

Visualization and comparison processes aimed at individualizing the marks are considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized)
- Lifting of 2D marks
- Casting techniques for 3D marks
- Preparation of inked exemplars

(e) Biological material (including DNA)

Identification and interpretation of biological material is considered a minimum service. (Note: actual DNA analysis is not considered as a minimum service but an additional service, to be included as part of a later laboratory upgrading phase). To achieve this, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized, including specialized photography, e.g., recording of luminol results)
- Stereomicroscopy

- Brightfield microscopy (including differential staining techniques, e.g. for spermatozoa)
- Spot tests (chemical colour/change tests)
- Immuno-chromatographic tests

(f) Questioned documents[10]

Documents

General questioned document examination (e.g., identification of printing methods, security features, signs of alteration, erasure and obliteration) including ink and paper fibre analysis is considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized under various illuminations)
- Stereomicroscopy
- Thin layer chromatography (for inks)

Handwriting

Comparison processes aimed at the individualization of handwriting (including signatures) are considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination
- Photography (under various illuminations)
- Stereomicroscopy
- Brightfield microscopy

(g) Firearms and toolmarks

Ammunition components and toolmarks

Comparison processes aimed at the individualization of the marks is considered a minimum service. To achieve this, the minimum is to implement the following techniques:

[10] Detailed information about forensic examination of documents, including equipment recommendation, is provided in the *Guide for the development of forensic document examination capacity*, United Nations New York, UNODC (2010), ST/NAR/42.

- Visual examination
- Photography (general and specialized)
- Casting techniques for 3D marks
- Stereomicroscopy
- Incident light comparison microscopy

GSR

Presumptive detection of GSR and assessment of muzzle-to-target distance is considered as a minimum service (GSR particle identification is considered part of a later implementation phase). To achieve this goal, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized, e.g., IR photography)
- Colour tests (to highlight the distribution of GSR on a target and assess the distance between the muzzle and the target)

Serial number restoration

Visualization of the information latent in the obliterated number is considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination
- Photography (general and specialized, i.e., macro-photography)
- Use of etching agents and other reagents to restore obliterated serial numbers and other obliterated markings

(h) Fire and explosions

Fire debris

Detection and identification of accelerant residues is considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination
- Photography
- Sample preparation (different techniques)
- Gas chromatography with flame ionization detector (GC-FID)

Explosives

Presumptive detection and identification of explosives are considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination
- Photography
- Brightfield microscopy (colour, physical appearance, and possible presence of taggants)
- Chemical spot tests
- Thin layer chromatography

(i) Fibres, paints, glass and other microtraces

Fibres/hairs

Observation and comparison aimed at identification and classification of the evidence are considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized under various illumination modes, coupled with microscopy)
- Sample preparation for microscopy
- Stereomicroscopy
- Brightfield microscopy (including polarized light microscopy)
- Microchemical tests (solubility and dye extraction)

Paint

Observation and comparison aimed at identification and classification of the evidence are considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized under various illumination modes, coupled with microscopy)
- Sample preparation for microscopy
- Stereomicroscopy

- Brightfield microscopy
- Microchemical tests (solubility and chemical reaction)

Glass

Observation and comparison aimed at identification and classification of the evidence are considered a minimum service. To achieve this, the minimum is to implement the following techniques:

- Optical examination (including multispectral imaging)
- Photography (general and specialized under various illumination modes, coupled with microscopy)
- Sample preparation for microscopy
- Stereomicroscopy
- Brightfield microscopy (polarizing filters)
- Density comparison

(j) Digital and multimedia evidence disciplines

Unlike many other forensic disciplines that may require a range of equipment for conducting different examinations, the equipment and supplies recommended for providing a minimum service for the digital and multimedia evidence disciplines are generally based upon:

- A computer workstation
- Write protection and analytical hardware and/or software (as applicable to the situation and sub-discipline)
- Validated forensic software

While there are common characteristics of workstations and software, the sub-discipline requirements drive the specific needs for data recovery and analysis tools within that discipline. Expansion beyond what is recommended for minimum service might include acquisition of a range of forensic software and hardware tools that may provide similar output with slightly different methodologies.

Computer forensics

The minimum service in the computer forensics field includes the forensic examination of computers, servers, networks, mobile telephones, and other digital devices with a more limited set of software than that used for a full service. To achieve this minimum service will require hardware and software to perform the following processes:

- Data recovery (including portable equipment for recovery done at the crime scene)
- Data extraction and analysis (incl. metadata, hidden and protected data)
- Reporting and archiving

Forensic audio analysis

Enhancement, authentication, comparison and duplication of audio recordings and associated metadata are considered the minimum service. To achieve this, the equipment recommended includes hardware and software to perform the following:

- Data recovery (including analogue and digital data formats)
- Data extraction and analysis (including data restoration, enhancement and authentication)
- Reporting and archiving

Forensic video analysis

Enhancement, authentication, comparison and duplication of video (and associated metadata) including digital media, tape, film, optical media, and other storage devices capturing video are considered a minimum service. To achieve this, the equipment recommended includes:

- Data recovery (including analogue and digital data formats)
- Data extraction and analysis (including data restoration, enhancement and authentication)
- Reporting and archiving

B. Provision of routine services

This second section presents the equipment recommended for routine casework in individual forensic science fields. Annex 2 presents an overview of the various techniques and their fields of application in forensic casework.

(a) Crime scene investigation

Without doubt, the most important step in any forensic investigation is the initial examination of the crime scene. The whole investigation can be compromised if critical evidence is missed, inadequately recorded, inappropriately collected or packaged, contaminated, or destroyed.

Work at the crime scene is the first stage in securing the physical evidence record.

All items required by the crime scene investigator should be arranged in suitable carrying cases to be easily transported to, and used at, the scene. There is no single recommended crime scene kit. Typically crime scene investigators complete their own kits, following the guiding principles listed below. (In some circumstances, cases on wheels may be desirable).[11]

Protection and safety

¤ Disposable latex or plastic examination gloves

¤ Disposable coveralls

¤ Hair caps

¤ Shoe covers

List of hazardous chemicals signs

Heavy gloves

¤ Crime scene barrier tape

¤ Disposable face masks (dust and anti-putrefaction masks)

¤ First aid kit

Detection

Magnifier

Rechargeable flashlight/torch/hand-held light source

Rechargeable hand-held forensic light source (basic)

Goggles

Collection

¤ Clear adhesive tape

¤ Disposable spatulas

Scissors

Scalpels

[11] Further information on recommended items for basic crime scene investigation kits as well as information on standardized kits developed by UNODC, can be requested from: lab@unodc.org.

¤ Disposable plastic tweezers

¤ Scalpel replacement blades

¤ Screw-cap test tubes

¤ Individually wrapped sterile cotton swabs

¤ Disposable plastic pipettes

Packaging

¤ Cardboard boxes

¤ Metal unlined cans for collection of arson evidence

¤ Bindle material/weighing paper

¤ Plastic bags

¤ Paper bags (small, medium, large)

¤ Slide boxes (for teeth, projectiles etc.)

¤ Envelopes (various sizes)

¤ Body bags

¤ Containers for sharp objects (e.g. knives, syringes)

¤ Evidence tags/labels

¤ Tamper-proof evidence tape

Documentation (including photography)

Rulers (30 cm)

Reference scales (L-shaped)

¤ Tape measure

¤ Writing pad

Clipboard

¤ Writing and marking pens, pencils, metal scribe, chalk, marking paint

¤ Paper towel

Stapler and ¤ staples

Magnet

Compact camera (for more detailed information on equipment and accessories related to photography, see part II, section *(l)*, page 69)

Under certain circumstances: single lens reflex camera digital (including range of lenses, ¤ spare batteries, lens brush, lens tissue, image storage cards, filters), memory card

Compass

Photographic tripod stand with water-level

Camera flash (and batteries)

Others

Stapler and staples (¤)

¤ Rubber bands

¤ Paper towels

Magnet

Compass

Specific collection and packaging supplies for biological material (if DNA technologies accessible)

¤ Buccal swab collection kit

¤ Individually wrapped sterile cotton swabs

¤ Aliquots of sterile water or saline

Fingerprints—equipment for powdering techniques

Brushes adequate for available powders

Magnetic wand applicator (for magnetic powders)

¤ Powders, such as magnetic powder, non magnetic powder

¤ Fingerprint tape, 1.5 inch

¤ Ink pad (for finger and palm)

¤ Lift card (white)

¤ 10-print forms for fingerprints (e.g., Interpol forms) (for more detailed information on accessories related to powdering technique, see part II, section *(g)*, page 63)

Shoemarks

2 D:

- Gelatine lifters

3 D:

See casting techniques

Casting materials

See part II, section *(d)*, page 51

Tool kit

e.g., hammers, saw, screwdrivers, wrench, pliers, knife, shovels, sifters, rake, bolt cutters, power drill, electrical extension cords, wire cutters, hacksaw, socket wrench set, rope, assorted sized of wood chisels, axe, cotton work gloves, pry bar

Portable equipment

Spot tests (see part II, section *(a)*, page 72, for colour tests)

Immuno-chromatographic tests (see part II, section *(h)*, page 68)

Note: for specific crime scenes, additional equipment and materials may be required.

(b) All types of forensic laboratories

Material collected at the crime scene will generally require some form of examination and analysis within a centralized laboratory facility. This central facility will require a minimum level of equipment and consumables in order to provide a minimum service with respect to general laboratory work. Additional resources are required for specific evidence categories and techniques.

Depending on services provided, not all items below are needed. Note that equipment for crime scene investigation can also be used in laboratory environment,

Protection and safety

Eye wash and safety shower

Hearing protection

Fire extinguisher, for use on wood, paper, flammable liquid and electrical fires

First aid kits (standard), including fire-resistant blanket

Waste collection and removal for chemical, biohazardous and other types of laboratory waste

Safe storage facilities for hazardous chemicals and potentially hazardous exhibits (e.g., chemicals and glassware from clandestine laboratories)

¤ Disposable latex examination gloves and white cotton gloves

Laboratory coats

Safety eyewear

Cleaning material (including appropriate disinfectants)

¤ Disposable face masks (dust and anti-putrefaction masks)

Optical detection, collection, packaging, documentation

Optical detection includes observation with the eyes only, with a magnifier, with forensic light sources (FLS) and with multispectral imaging systems (see part II, section *(l)*, page 69, for more detailed information on multispectral imaging systems).

Detection

Hand-held light source

Magnifiers

* Forensic light source covering a wide range of wavelengths

UV lamp (254 and 366 nm)

Light-proof viewing cabinet (required if room cannot be fully darkened)

Full range of viewing goggles and camera filters

Collection

¤ Lifting materials (assorted adhesives and gelatines)

¤ Adhesive tape (assorted)

Spatulas, assorted

Scissors

¤ Tweezers and disposable tweezers, assorted

¤ Scalpels (including disposable), both round and pointed blades with replacement blades

Packaging

¤ Evidence packaging supplies: various types and sizes of collection bags/boxes (envelopes, paper bags, plastic bags, pillboxes, metal paint cans and lids, cardboard boxes, screw-cap glass vials, paper)

¤ Evidence tags/labels

¤ Evidence sealing tape

Documentation

Rulers, reference scales

¤ Cotton tips applicators

Swabs

Digital[12] camera (for specific equipment related to photography, see part II, section *(l)*, page 69)

Case files, exhibit logs, and appropriate examination record sheets

Small tool kit

¤ Writing paper, graph paper, report paper

¤ Pens, pencils, markers etc.

General laboratory equipment and materials

Refrigerator (explosion-proof)

Oven

Fume hood (for handling toxic and flammable chemicals)

Biohazard hood (for handling biohazardous materials)

Hot plates or heating mantles

Ultrasonic bath

Mortars and pestles

Spot test plates

[12] A digital camera is recommended when purchasing a new camera. Traditional cameras can still be considered for use if available.

Test tube stands

Test tubes and corks (or screw-cap test tubes)

Supports (rectangular base with clamps, and ring support with clamps)

Tubing (regular and thick-walled for vacuum)

Magnetic stirrer and stirring bars

Timer/clock

¤ Silicone grease

Bunsen burner (with suitable gas supply—can be portable butane/LPG)

¤ pH indicator paper, 0-14

¤ Swab boxes

¤ Paper towels

¤ Parafilm® M sealing film

Computer, including CD burner and office application software (eg. word processing, spreadsheet, etc.)

Scanner

Printer

LAN with Internet access

Glassware

Beakers, assorted from 5 to 1000 ml

Erlenmeyer flasks, assorted from 10 to 2000 ml

Test tubes, length 130 mm, diameter 25 mm

Desiccators with disc, vacuum, safety, with screw thread connection stopcock in lid, top ID 250 mm

¤ Desiccant

Glass tubing

Glass rods

Dispensing flasks fitted with eye-droppers

Glass stoppers, assorted

Reagent flasks

¤ Reagent labels

¤ Pasteur pipettes

¤ Teats for Pasteur pipettes

Volumetric measurements

Graduated cylinders, assorted from 5 to 1000 ml

Graduated pipettes, assorted from 1 to 10ml

Volumetric pipettes, assorted from 1 to 25 ml

Volumetric flasks, assorted from 5 to 1000 ml

Weight measurements

* Analytical balance, 0.1 mg resolution with internal calibration

Top-pan balance, 0.01g resolution

Calibration weights

¤ Weighing dishes (e.g. disposable plastic boats)

Solution preparation

Beakers, assorted from 10 to 1000 ml

Conical flasks, assorted from 50 to 2000 ml

Graduated cylinders, assorted from 5 to 1000 ml

Electric hot plate/magnetic stirrer unit

Magnetic stirrer bars (assorted)

Extraction and separation

Mechanical shaker

Centrifuge

Rotary beater

Vortex

Vacuum pump

Recirculation chiller

Soxhlet apparatus

Thimbles

Separator funnels 50, 100 and 200 ml

Funnels for gravity filtration, diameter 40-60 mm

Buchner funnels for vacuum filtration, diameter 65-85 mm

Suction rubber adaptor set

Centrifuge tubes

¤ Filter paper, assorted from 7 to 12.5 cm

¤ Large sheet of filter paper and Benchkote®

Distillation and evaporation

Rotary evaporator

Water distillation apparatus for distillation of tap water including storage container with outlet

Diagonal condenser including a receiving and an evaporating/rotating flask (vol. 1L)

Round bottom flasks, assorted from 50 to 1000 ml

Supports for round bottom flask, assorted

Laboratory jacks

Water bath

Clamps

Related skills requirements

Experience in the use of extraction techniques, including dry and immiscible solvent extraction for the separation and isolation of individual compounds from known mixtures (e.g. drug samples); good understanding of acid/base equilibriums and partition coefficients.

C. Specific techniques

(a) Blood pattern analysis

Protection and safety

¤ Disposable barrier-protective coveralls eg: Dupont™ Tyvek®

¤ Shoe covers (barrier protective)

¤ Half-face negative pressure respiratory protection equivalent to P2 or higher

Eye protection

Disinfectant for decontamination of equipment eg Virkon®, disposable alcohol wipes etc.

Detection

* Rechargeable hand-held forensic light source with UV and IR capability (with associated coloured and polarized photographic filters and goggles)

Stereo microscope with phototube

Anastigmatic photographic loupe with measurement graticule

Jewellers' magnifying headset loupe

Documentation (including photography)

Rulers (1 metre)

Tape measure with larger scale increments for higher visibility in photographs e.g. 2 metre x 25mm Yamayo Model C Mini-Rod - Pocket Style

¤ Assorted size reference scales (both solid plastic and adhesive disposable)

¤ Elasticised "hi-visibility" builders string or similar

¤ Strapping tape or other re-enforced adhesive tape

Vernier callipers

Scientific calculator

Zero base-line protractor eg Evi-Paq® trajectory protractors

* Most modern SLR cameras have high quality low pass filters that block IR light. An IR capable SLR camera is desirable for dark fabric examinations.

Other

Photographic software e.g. Adobe Photoshop®

* Bloodstain pattern analysis software eg BackTrack™ and Hemospat™

(b) Casting techniques for 3D marks

Casts are required to record 3D marks, such as shoe marks, tyre marks, tool marks, and indented fingerprints.

Checklist of materials and accessories

¤ Dental stone and plaster of Paris for shoe and tyre prints, preferably premeasured amounts of dental stone sealed in mixing bags

Bucket, bowls and/or plastic bags for mixing

Bags or jars with appropriately premeasured amounts of water

Wooden spatula

Wire or wooden splints for support, or casting forms

¤ Silicone casting material for tool marks and indented fingerprints [tube]

Related skills requirements

Awareness of the importance of describing and documenting (especially photography) the mark before collection.

Ability to prepare and apply the casting material in an acceptable manner without damaging the mark.

Ability to adapt the technique to the prevailing environmental conditions.

(c) Density analysis

Density analysis is typically used for the comparison of soil fractions but can also be used for the comparison of glass fragments in the absence of refractive index (RI) measurements. As density and RI are closely correlated parameters, it is generally considered that density analysis is not required if RI values can be obtained.

Checklist of materials and accessories

For soil: density-gradient tubes (6-10 mm diameter, 25-40 cm length)

For glass: test tubes or large vials

¤ Liquids of appropriate density (organic liquids are commonly used, but inorganic mixtures are recommended as they are less toxic)

Related skills requirements

Understanding of the density gradient theory (soil).

Ability to prepare the gradient tubes and the sample (soil).

Ability to compare the density of two glass fragments.

Understanding of the limitations of density comparison compared to RI measurements (glass).

(d) Digital and multimedia evidence analysis

Core equipment and supplies for working with digital and multimedia evidence

Described below are equipment and supplies which are generally accepted to be required for the examination of digital and multimedia evidence regardless of the sub-discipline. It is expected that experts in the field of digital and multimedia evidence will have the knowledge and practical ability to use the electronic equipment, software and related supplies.

The methods (processes and software) and equipment used should be tested and validated to establish the output as reliable and repeatable. Maintenance is conducted in accordance with manufacturer's recommendations, including upgrades to the internal Basic Input Output System (BIOS), and internal hardware components. Generally, the Power-On-System-Test (POST) is considered to be the standard for performance verification of computer equipment placed in service after test and validation of procedures have been completed. A record should be maintained of all maintenance activities for the life of the equipment.

As is the case with hardware, baseline software applications and operating systems for the computer forensic workstation will be quite similar across the sub-disciplines. Generally, most forensic workstation operating systems are Windows-based, although Mac, Linux, Unix-based and proprietary software operating systems are available.

While operating system software and some analytical software programs may be considered "axiomatic", based upon their long-term use (Windows XP, Microsoft Word, or Nero, for example) they should be run through a verification process using standard controls, comparing the results to expectations. This verification process should be documented prior to beginning any casework.

New tools and analytical software used to perform evidentiary analysis should be tested and validated prior to being used in casework. Subtle improvements and new features in forensic applications should be documented, but major changes in these forensic applications are cause for re-testing and validation.

Operating system software, antivirus software, and other software applications used in casework should be updated in accordance with the manufacturer's distribution and recommendations for installing upgrades and patches. A log should be kept of all upgrade and maintenance activities.

Computer workstation

Equipment

- Laboratory forensic workstation with monitor, output devices (CD/DVD) and connections (i.e., USB, Firewire, SATA) (may be discipline-configured by vendor) configured with operating system (i.e., Windows or Linux) and user-based software applications (i.e., Office, anti-virus); special configuration considerations include a high-end processor, a significant amount of random access memory (RAM), high quality video and audio components, DVD and CD drives, multiple peripheral connection capabilities for IDE, SCSI, SATA, USB, Firewire, and networks.
- Laptop or portable forensic workstation with similar configuration and capabilities to those of the laboratory forensic workstation (may be discipline-configured by vendor)
- Uninterruptible power supply (UPS) for backup power
- Isolation transformer (power/voltage regulation) for PC workstations and audio/video equipment
- Networking equipment (if the laboratory is configured as a network rather than standalone workstations)
- Internet connectivity for updating software and research
- General use printer (color)
- Digital camera

Other supplies

Cables and connectors

Power surge protectors/extension cords of various lengths

Hard drives

Compact flash cards (various sizes and volumes)

Small computer instrument toolkit

Anti-static wrist band

Equipment cleaning supplies

Additional core equipment for computer forensics

RF shielding equipment for mobile telephone examinations (can be designed into the lab infrastructure)

Related skills requirements (computer forensics)

Ability to identify digital storage devices at a crime scene and to properly secure the digital evidence in its native format

Ability to implement equipment and software performance verification (check that the equipment and software performs as intended or expected)

Additional core equipment for forensic audio analysis

Professional grade headphones and speakers

Professional quality players supporting various formats and CD/DVD recorders

High quality audio cables and terminations appropriate to the equipment in the lab: analog audio cables, digital audio cables

Related skills requirements (forensic audio analysis)

Ability to identify audio recording systems and devices at a crime scene and to properly secure the audio recording evidence in its native format

Ability to implement equipment and software performance verification

Additional core equipment for forensic video analysis

High resolution monitors

Professional quality player of various media formats and DVD recorders.

High quality video cables appropriate to the equipment in the lab: analog video cables, digital video cables

Image printers

Colour calibration equipment for monitors and printers

Related skills requirements (forensic video analysis)

Ability to identify video recording systems and devices at a crime scene and to properly secure the video recording evidence in its native or proprietary format

Ability to implement equipment and software performance verification

Data recovery: write protection, imaging and hash verification

Data recovery

Digital and multimedia disciplines focus on data. The data can be stored digitally, as on a hard drive, or in analog format such as with some audio or video tapes. The primary purpose, goal and mission of an examiner in this field is to recover the original data for further analysis without making deleterious changes.

Write protection

To ensure integrity of the image during the copying and examination processes, the image is acquired using tested and validated software applications or hardware devices that prevent alteration to the original data. Although several software solutions are available for write protection of data, the most commonly used write protection is implemented through hardware devices (write protection devices) that attach between the forensic workstation and the original digital storage device, or are included in standalone devices designed to image hard drive (original) to hard drive (image). Several vendors produce these write-protection or standalone hardware devices.

Imaging (copying)

It is generally accepted that digital evidence should be imaged and the analysis conducted on a validated image rather than the original data. The reasons include the volatility of digital data and the fragile nature of the devices upon which they are stored. Creating a validated image provides the expert with the option to go back to the original evidence, in the event that the image is damaged or inadvertently altered. Analysing a verified image reduces the risk of inadvertent changes to original data or loss of data should the original hardware storage device fail ("hard drive crash"). Note that although it is common practice to image the entire drive or medium in computer evidence cases, often in audio and video examinations this is not a requirement and any hash verified copy of the multimedia files to be examined is sufficient.

Imaging the original data requires that the image destination (often a hard drive or tape) be forensically cleaned or wiped of data to prevent data contamination. If the destination for the image is another digital hardware device, like a hard drive or virtual disk, it is "forensically" wiped using vendor-based software applications or hardware devices which have been tested and validated to ensure that no user data remains on the destination device. Properly used, this prevents the cross-contamination of digital evidence. Formatting a disk will NOT delete user data.

Hash verification

Verification of the data imaging process, to ensure data integrity of the copy, is achieved through the use of a cryptographic hash algorithm. The hash calculates the digital data read from the original device and compares it to the data copied to the forensically wiped destination providing a unique digital value, often referred to as a digital fingerprint. If the data read and data copied hash values match, the image is considered verified.

Equipment and supplies for data recovery

- Data storage hardware (forensically clean)
- Write protection hardware and software
- Hard drive imaging hardware and software
- Hash algorithms (often incorporated into the hardware or software used for imaging)

Related skills requirements

- Ability to disassemble digital hardware storage devices and computers, removing hard drives, proper cabling of digital devices, invoking proper jumper settings, powering digital devices, and reassembling to return to their original state.
- Ability to identify and document damage to storage media or equipment under examination.
- Ability to attach and configure write protection hardware and to use/configure software write protection to ensure original data integrity.
- Ability to forensically prepare media (wipe existing data) to receive images or analysis output of the suspect digital data.
- Ability to determine the requirements for write protection.
- Ability to configure imaging hardware, software, and forensic equipment.
- Ability to invoke hash verification algorithms throughout the process.
- Ability to interpret hash verification results.

Additional equipment for data recovery in forensic audio cases (analog source data)

- Equipment and supplies to inspect and repair analog audio recordings.
- Professional analog audio-editing applications to review recordings, and prepare for basic studio audio processing and file format export or digital conversion.

Related skills requirements

- Ability to disassemble analog storage devices, removing audio tapes, proper cabling of analog devices, invoking proper jumper settings, powering analog devices, and reassembling to return to their original state.

- Ability to examine audio tape, identify tape damage, and conduct repair for continued analysis.

- Ability to attach and configure analog editing equipment.

- Ability to forensically prepare media (wipe existing data) to receive audio output.

Additional equipment for data recovery in video analysis (analog source data)

- Equipment and supplies to inspect and repair analog video recordings.

- Professional digital video editing applications for recording, basic studio processing and file format export.

Related skills requirements

- Ability to disassemble analog storage devices, removing video tapes, proper cabling of analog devices, invoking proper jumper settings, powering analog devices, and reassembling to return to their original state.

- Ability to examine video tape, identify tape damage, and conduct repair for continued analysis.

- Ability to attach and configure analog editing equipment.

- Ability to forensically prepare media (wipe existing data) to receive video output.

Data extraction and analysis

The data extraction and analysis phase of the forensic examination is generally the point of divergence between the three sub-disciplines. This phase includes the use of forensic tools to organize the imaged data in a way that allows for it to be searched through, sorted, filtered, and extracted. While the general concepts of data recovery, enhancement, authenticity, extraction, and output between the three may be similar, the forensic methodologies, equipment configuration, and software applications are often different. Within each sub-discipline there are commercially available software applications that are used in conjunction with data forensic recovery and analysis software to provide output in a user-friendly format. The type of device, operating system (if applicable), and software used to store the data under examination will define the appropriate methodology, including software and hardware required, to produce the examination results.

Checklist of equipment and supplies

Equipment/supplies for data extraction and analysis in computer forensics

Forensic software for data extraction and analysis including but not limited to:

- Automated forensic software applications or tested/validated freeware tools
- Steganalysis software
- Hash algorithms
- Password cracking or decryption software and hardware
- Extraction of volatile (running) system processes ("live") software
- User applications that enable a reconstructed view of the original suspect data (may be built into the forensic suite)

Related skills requirements (data extraction and analysis in computer forensics)

- Ability to interpret digitally stored data, including metadata from files and folders recovered.
- Ability to examine and interpret computer forensic artefacts (Internet history, temporary Internet files, email, etc.) to provide a timeline analysis of events that occurred on a computer or other digital device under examination.
- Ability to use computer forensic software for password cracking and defeating encryption.
- Ability to use software to identify steganography and identify files or data which may be hidden.
- Ability to invoke other software and hardware techniques to analyse data.
- Ability to analyse advanced or non-traditional computer operating systems or proprietary software applications.
- Ability to analyse mobile telephone devices.
- Ability to analyse unique digital devices (e.g., global positioning systems, entertainment systems).
- Ability to extract data from a live computer or network using advanced forensic extraction tools and methodologies.

Equipment/supplies for data extraction and analysis in forensic audio analysis

- Signal generators to produce standard test signals (tones, white noise) for running equipment control tests and signal analyzers for measuring amplitude/power, stereo phase, frequency spectrum, and jitter eye pattern

- Forensic analysis software
- Additional audio/video editing software to extract and merge audio streams

Related skills requirements (data extraction and analysis in forensic audio analysis)

- Ability to configure and operate audio recording and playback equipment
- Ability to use forensic software (including proprietary software/equipment) to extract electronically stored audio data
- Ability to use processes for tape enhancement and playback optimization, clarity, noise reduction, voice identification, recording authentication[13]
- Ability to identify and apply filtering processes appropriate to the source of signal degradation
- Ability to optimize compression algorithms for signal quality of output products

Equipment/supplies for data extraction and analysis in forensic video analysis

- Signal generators to produce standard test signals for running equipment control tests and analyzers to measure signal properties
- Forensic analysis software
- Additional video/audio editing software to extract and merge video streams

Related skills requirements (for data extraction and analysis in forensic video analysis)

- Ability to operate video recording and playback equipment
- Ability to implement processes and procedures for video recording brightness, contrast, clarity, de-interlacing, de-multiplexing, stabilizing, conduct fame averaging, conversion of time lapse to real-time, and playback optimization
- Ability to use software to isolate individual video frames/fields, verify their integrity (hash), print, export, and archive

[13] For advanced signal content analysis such as speaker identification or gunshot analysis it is recommended that a qualified expert be consulted who has detailed knowledge of the phenomenon producing sound (phonetics/linguistics, firearms, etc.), its measurement limitations and sources of error, conditions affecting variability, interaction of the phenomenon with recording systems, and statistically typical behaviour of the phenomenon in an appropriately sampled population. This knowledge may be beyond the scope of many laboratories.

- Ability to use video analysis software for recovered data analysis and examination, authentication, enhancement, comparison, evaluation, extraction and output[14]
- Ability to identify noise components (spectral, random, structured), resolution, image and signal degradation causes, and compression effects.
- Ability to identify and apply filtering processes appropriate to the source of signal degradation

Reporting and archiving

Once the overall data analysis has been completed, the data of interest is organized for export or review by the customer. Once organized and/or the customer has selected the required data for export, the reporting phase is initiated.

Equipment and supplies for reporting and archiving in all DME sub-disciplines

- Storage media

(Note: no equipment or software beyond the core required workstation is needed)

The output generated by each discipline can range from printed materials to digital data electronically copied to hard drives, CDs, or DVDs. The associated equipment will include general purpose printers to photo quality printers, and internally installed CD/DVD Read-Write drives, and externally peripheral devices for similar processes that are part of the core workstation. Choices of file formats, codec and resulting tradeoffs in quality may be necessary to comport to the submitter's review capabilities (i.e. CD v DVD, VHS tape). The output format of archived examination will be driven by such factors as the policies, procedures, and budget of the unit conducting the examination.

Related skills requirements

- Ability to write a report that describes in non-technical terms the forensic processes and output of the examination
- Ability to organize the extracted data for investigative or prosecutorial review
- Ability to archive forensically recovered data for future use in court
- Ability to copy and export audio and video recordings or extract probative audio segments

[14] For advanced image analysis or comparison such as visual object identification, character recognition or medical diagnosis, it is recommended that a qualified expert be consulted who has detailed knowledge of the particular objects or phenomenon being imaged (manufacturing processes, medical specialties, etc.), conditions affecting variability, measurement limitations and sources of error, interactions and limitations to imaging the phenomenon with particular imaging systems, and statistically typical behaviour of the phenomenon in an appropriately sampled population. Additionally, the expert should have the ability to test the behaviour of imaging systems to produce a statistically robust model of performance and measurement characteristics. This knowledge and ability may be beyond the scope of many laboratories.

(e) DNA analysis

DNA analyses, also known as DNA profiling, DNA testing, DNA typing, or genetic fingerprinting, involve the extraction, purification, amplification, sequencing and detection of unknown or suspected DNA traces in a laboratory and their comparison with known/unknown DNA profiles to determine their source.

Checklist of equipment, materials and accessories

For equipment related to collection and anti-contamination protection measures at the scene, see part II, section A on crime scene investigation, on page 33.

DNA extraction and purification

Equipment, materials and accessories

Various microfuge tubes including standard and spin baskes

Tube decappers

Tube racks

¤ Scalpels, razor blades, tweezers

Bench or butcher paper, weighing paper, weighing boats for sample manipulation

¤ Disposable face masks in addition to lab coats

¤ Various gloves

Bio-waste containers

Sharps disposal containers

Appropriate buffers for extraction technique

Microcon or centricon tubes for purification

Microfuges and centrifuges for centricons if using

Commercial chromatographic separation tubes if using

Robotic equipment and supplies if using

Negative and positive control samples as appropriate

¤ Cleaning and decontamination reagents such as appropriate preparations of bleach and alcohol

Polymerase chain reaction

Equipment

Separate room with appropriate air flow and floot traffic flow

* PCR thermal cycler (automatic rapid and precise temperature changes, e.g. GeneAmp PCR System 9700)

Materials and accessories

Amplification set-up hood with appropriate air flow

¤ PCR kits (enzymes, primers)

¤ Buffer solutions

¤ PCR kits (enzymes, primers)

¤ Tubes, caps, trays for PCR

Bio-waste containers

Sharps disposal containers

Cleaning and decontamination reagents such as appropriate preparations of bleach and alcohol

Automatic sequencing and detection (capillary electrophoresis)

Equipment

* DNA Sequencer (e.g., ABI PRISM 310 , 3100, 3130))

Materials and accessories

¤ Gloves

¤ Buffer solution and waste receptacles

¤ Fittings and filters

¤ O-rings

¤ Syringes

¤ Tubes, trays, septa and adapters

¤ Capillaries (e.g.: 47 cm, 61 cm) and Polymers (e.g.: POP-4, POP-6)

¤ Formamide for denaturization

Allelic ladder

¤ Sequencer buffers

¤ Running buffer

¤ DNA sequencing kits

Software (e.g., GeneScan™ , GenoTyper™ , GeneMapper™)

Extra computers for data interpretation

LAN for data storage and back-up

CD burner for data storage and preparation of discovery

Related skills requirements

Theoretical

Awareness of the importance of the extraction and purification process. The quality of the final profile will depend on this step.

Knowledge of the various methods for DNA extraction and purification (e.g., CHELEX, kit QIAGEM, organic extraction, DNA IQ).

Knowledge of the PCR process (DNA polymerase, primers, inherent and spurious artefacts).

Awareness of the power of replication and the amplification, and the consequences in case of sample contamination, either prior to receipt or in the laboratory.

Understanding that PCR will not provide information in isolation; it is a first obligatory step before DNA-typing by capillary electrophoresis.

Knowledge of the wide range of commercial kits for PCR amplification (e.g., Profiler Plus, Identifiler, Powerplex 16, SGM+, Identifiler for forensic purposes).

Awareness of advanced profiling methods, such as low copy number analysis, their advantages and limitations.

Experimental

Ability to apply specific procedures on different types of evidence (e.g., cigarette butts, stamps, hairs, bones).

Ability to properly extract and purify sample for PCR.

Ability to implement the stringent requirements necessary for preparing and amplifying samples.

Ability to use the automated capillary analysis instrument, chemistry, hardware, software, sample loading, programming.

Ability to correctly interpret DNA profiles (including low quality samples, low quantity samples and mixed profiles) and to apply appropriate statistics for the determination of evidential value.

(f) Electrostatic imaging systems

Electrostatic imaging systems are typically used on questioned documents. They work by creating an invisible electrostatic image of any indented impressions on the paper. This image is then visualized by the application of a charge-sensitive toner mixture. The sensitive imaging process reacts to sites of microscopic damage of fibres at the surface of the document, which have been created by dynamic pressure interaction with overlying surfaces during the act of writing. An electrostatic technique (simpler versions which are field portable) can also be used to lift dusty shoemarks off surfaces such as carpet.

Checklist of equipment, materials and accessories

Electrostatic detection apparatus

Humidifier

Shoeprint lifter

¤ Toner

¤ Rolls of plastic film

¤ Result archival sheets

¤ Metallised lifting sheets (for shoeprint lifter)

Related skill requirements

Ability to use optimal humidity conditions for best results.

Awareness of the destructive aspect of humidification for paper, ink, and latent fingerprints if exposure is too long.

Awareness of the possibility to detect fresh fingerprints with this technique.

Awareness of the non-destructive nature of the technique

Awareness of the ozone generated during the electrostatic charging process and the need for adequate ventilation or the use of a fume hood if prolonged operation is envisaged.

(g) Fingerprint detection and enhancement techniques

(Powdering, DFO, ninhydrin, indanedione, physical developer, cyanoacrylate fuming, luminescent stains, detection of blood marks, detection on adhesive surfaces, etc.)

The detection of fingerprints involves a range of detection methods, depending on the condition of the fingemarks, the location where, and the surface on which, they are found:

- *Optical detection methods* are non-destructive and are employed prior to the application of other techniques. Optical methods generally require the use of a high-intensity forensic light source (FLS) that can be operated at various wavelengths. These methods are also required for visualization after the application of particular detection methods (e.g. luminescence visualization after DFO or indanedione development). Appropriate photographic equipment is required to ensure that any fingerprint detail is captured under optimum conditions.

- *Powdering* is the traditional fingerprint detection technique on smooth non-porous surfaces, particularly at the crime scene. Particles adhere to the humid, sticky, or greasy substances in the latent fingerprint deposit.

- *DFO, Ninhydrin, Indanedione* are amino acid reagents for the detection of latent fingerprints on porous surfaces such as paper.

- *Physical Developer* is used for the detection of latent fingerprints on porous surfaces that are or have been wet (a condition that precludes the use of amino acid reagents).

- *Cyanoacrylate* (Superglue®) forms a vapour that reacts with certain eccrine and sebaceous components in latent fingerprints. The vapour polymerizes on the ridges of the marks. The technique is used for fingerprint detection on non-porous surfaces such as glass, plastic and metal. Fingerprints developed by cyanoacrylate fuming can be further enhanced by the application of a luminescent stain such as rhodamine 6G or basic yellow 40.

- *Detection of fingerprints in blood ("blood marks")*: Diaminobenzidine and Amido Black (a protein stain) are reagents for the enhancement of fingerprints in blood on both porous and non-porous surfaces. Such techniques should only be applied after optical detection techniques and techniques that develop latent fingerprints have been exhausted.

- *Detection on adhesive surfaces:* Sticky-Side Powder is a thick powder suspension for the development of latent fingerprints on the sticky side of adhesive tape and adhesive labels.

- Other techniques considered beyond the scope of this manual:

  – *Vacuum metal deposition (VMD)*

    VMD is extremely sensitive for the detection of fingerprints on a variety of non-porous and semi-porous surfaces, and can be employed in sequence with other development techniques. Gold is evaporated under vacuum to form a very thin layer of metal on the surface under examination. A layer of a second metal, usually zinc, is then deposited in the same manner.

– *Multimetal Deposition (MMD)*

MMD can develop fingerprints on a wide range of porous, semi-porous and non-porous surfaces. The technique may be useful on difficult surfaces. However, the reagents are time consuming to prepare and apply, which limit their routine application.

Checklist of materials and accessories for optical detection methods

Multi-wavelength forensic light source (FLS)

Imaging equipment including camera (preferably digital), filters, tripod, camera stand, etc.

Checklist of materials and accessories for powdering

Brushes (e.g. squirrel-hair, camel-hair, fibre glass filaments, feathers, etc.)

Magnetic wand applicator (for magnetic powders)

¤ Fingerprint powders (different colours, magnetic, fluorescent)

¤ Lifting materials (assorted adhesive and gelatine lifters)

Forensic light source, with filters, or UV lamp (for fluorescent powders)

Checklist of equipment, materials and accessories for DFO, ninhydrin, indanedione methods

Laboratory oven or dry heat press (for DFO or indanedione)

¤ Reagents (ninhydrin, DFO, indanedione, appropriate solvents)

Checklist of materials and accessories for physical developer

¤ Reagents (silver nitrate, ferrous ammonium sulphate, ferric nitrate, citric acid, Synperonic N, N-dodecylamine acetate, good quality distilled or deionized water)

Checklist of equipment, materials and accessories for cyanoacrylate methods

* Cyanoacrylate fuming chamber (commercial or home-made)

¤ Cyanoacrylate adhesive

¤ Staining solution for enhancement after cyanoacrylate treatment (requires luminescent dye such as rhodamine 6G and appropriate solvents)

Checklist of materials and accessories for detection of fingerprints in blood ("blood marks")

¤ Reagents for diaminobenzidine and/or amido black

Checklist of materials and accessories for detection on adhesive surfaces

¤ Reagents and powder for Sticky Side Powder

Related skills requirements

Awareness of the nature of the latent fingerprint deposit and the influence of environmental factors.

Awareness of the evidential value of fingerprint evidence and the degree of detail required for the identification of a fingerprint.

Awareness of the importance of tests on similar items serve as controls to determine that the detection process is working correctly.

Knowledge of the sequence for each type of support (i.e., porous, non-porous).

Familiarity with specific sequences when fingerprints are contaminated with blood or are on particular surfaces (e.g. adhesive surfaces, cartridge cases, human skin).

(h) Immuno-chromatographic tests

Immuno-chromatographic tests are based on the concept of specific antigen-antibody reactions and are used for the testing of biological material.

Checklist of equipment, materials and accessories

¤ Commercial test kits for human blood, human semen, human saliva, drugs

Related skills requirements

Knowledge of true cross-reactivity vs. over-sensitivity of the test (e.g., true positive results caused by minute amounts physiologically present in another fluid).

Awareness of the scope of the information provided by the results (e.g., possible blood, possible saliva, possible semen or not, possible human blood or not).

Knowledge of the theory of immuno-chromatographic techniques.

Awareness of the importance of the concentration of the sample (i.e., if too diluted or too concentrated, there will be a loss of sensitivity).

Awareness of handling/storage requirements to avoid degradation.

(i) Inked exemplars

Inked exemplars are crucial for comparison of fingerprints or shoe marks with fingerprints or shoe prints from a suspect.

Checklist of materials and accessories

¤ Fingerprinting ink and roller

¤ Ink removing agent for hands and for soles

¤ Ink and roller for shoes and tyres

Glass base or plate

Stand for shoes

¤ 10-print forms for fingerprints (e.g., Interpol forms)

¤ Strong transparent plastic sheets for shoes and tyres and tape/protective sheet to cover and store reference prints

Related skills requirements

Ability to obtain high-quality reference prints using black ink

Awareness of the risk that some detail may disappear if too much ink is applied

Awareness of the importance of properly labelling the inked reference prints, including information such as left or right shoe, case reference number, date, etc.

(j) Microcrystal tests

Microcrystal tests are quick, simple, and extremely sensitive tests for the identification of substances and their optical isomers. They involve formation of crystals from the reaction of the target compound with a chemical reagent, followed by the analysis of the resulting crystals (size, shape and colour) by means of a polarizing microscope and comparison with reference material, usually photographs of known crystals.

Checklist of equipment, materials and accessories

* Testing and volatilizing reagents

* Microscope with set of polarizing filters (polarizer and analyser)[15]

¤ Glass microscope slides (“cavity slide”), approx. 76x26 mm

¤ Cover glass 18x18 mm

[15] If a polarized microscope is available in the laboratory, it is also suitable for the observation and identification of microcrystals.

Related skills requirements (in addition to skills required for microscopy)

Knowledge of the expected results for the various drugs

Ability to use crossed polarizing filters

Experience

(k) Multispectral imaging

Multispectral imaging techniques use wavelength bands across the visible range as well as bands outside the visible (e.g. ultraviolet and near-infrared). As is the case with other optical detection methods, they are non-destructive. One application of multispectral imaging techniques is the document optical detection apparatus which compares documents and document features through the use of variable filters and irradiation in the ultraviolet, visible and infrared regions of the electromagnetic spectrum. Another application is for the detection and enhancement of latent fingerprints. Multispectral imaging systems can be purchased as an "all-in-one" system (e.g. VSC, Docucenter, Poliview) or as separate items, including forensic light source, camera, computer, image enhancement software, etc.

Checklist of equipment, materials and accessories

* Multispectral imaging system (e.g., Foster and Freeman VSC, Projectina Docucenter 4500, Rofin Poliview), including:

Multi-wavelength light source

Camera

Barrier filters

Computer

Image enhancement software

Printer

This equipment can also be purchased with a microspectrophotometer (MSP) capability, see part II, Spectroscopic/spectrophotometric techniques, section F, page 90, for equipment and related skills.

Related skill requirements

Understanding of the theory of light and its interaction with matter, e.g., absorption and luminescence phenomena when observing ink traces and paper characteristics.

(l) Photography

An important aspect of any forensic work is the need to carefully document all items received for examination and all relevant observations that are made. While general note taking can capture a significant amount of information, the value of photography —for the general recording of evidence and the recording of details—cannot be overstated. This is relevant for all forensic disciplines. As a result, a good equipment base with respect to photographic techniques is a priority area when establishing any forensic capability.

Checklist of equipment, materials and accessories

Digital[16] single lens reflex (SLR) camera

Spare camera batteries

Range of lenses (normal, wide angle and macro)

Lens brush and lens tissue

Image storage cards (e.g. compact flash cards)

Photographic tripod stand

Light meter

Flashlight (and batteries)

Copy stand, with supports for evidential material

Filters

Computer with storage space for both original images (untreated) and treated/processed images

Image processing software (e.g., Photoshop)

Printer (suitable for producing photographic-quality printouts)

Digital compact camera

Spare camera batteries and/or charger

Related skills requirements

Knowledge of light and photographic theory.

Ability to override automatic camera settings when required.

[16]A traditional camera can be used if already available, but it is not recommended to acquire a new traditional camera. Consider the need for films and chemicals if using traditional photography. A compact camera is sufficient for general photography.

Ability to select appropriate conditions and format adapted to the application.

Ability to use micro/macro photography, including colour or polarized filters.

Knowledge of colour balance to ensure that images accurately reflect reality.

Awareness that original pictures/images have to be available at any time during the investigation or in front of the court, and the need to secure these images appropriately.

Ability to use software to modify images and procedures needed to ensure chain-of-custody regarding modifications (e.g., use of scripts).

(m) Serial number restoration techniques

These techniques are usually applied to metallic components of firearms and vehicle engines. After smoothing and polishing, the application of certain etching reagents on the metal surface where the original numbers/markings have been removed, or overwritten by a new set of numbers/markings, can retrieve the original entries. The differential etching of the metal surface bearing the punched numbers/markings and the neighbouring blank area generates a contrast allowing visualization of the obliterated numbers/markings.

Checklist of equipment, materials and accessories

¤ Reagents (typically acids with the inclusion of selected metal cations, e.g., copper, chromium or iron, depending on the application

¤ Sandpaper to polish surface (various types of grinding compounds, various grades of silicon carbide paper)

¤ Modelling clay to delimited an area for chemical treatment

Magnaflux (fine iron oxide or ferrite particles used dry or suspended in a thin oil, e.g., kerosene), including a strong magnet and a vibrating tool

Oxy-acetylene equipment for number restoration by heat treatment

Related skills requirements

Awareness of the fact that the success of the technique depends on the thoroughness of the obliteration (i.e. if too deep, it will not be possible to restore the obliterated numbers).

Ability to adequately prepare the surface (cleaning, polishing to a mirror-like finish).

Awareness of temporary nature of results of serial number restoration (i.e. immediate photography is obligatory).

Knowledge of a range of reagents and options and have in-depth experience and recent practice with any reagent that is going to be applied to evidence items.

Awareness that it is the localized work-hardening of certain metals caused by the stamping operation that allows for the differential etching to reveal the pattern of the previously stamped characters to be revealed.

(n) Spot tests (colour, luminescence, solubility tests)

Chemical spot tests (colour tests) are simple chemical procedures in which the reaction between a chemical reagent and a target substance produces one or more characteristic observables, e.g. a colour, odour or luminescence (or the target substance is soluble/ insoluble in the case of solubility tests). Chemical spot tests are mostly non-specific (exception: cannabis) and presumptive in nature.

Such tests may be used for a range of materials including drugs and precursors, explosives, gunshot residues (GSR), biological material (e.g., blood and semen), textile fibres, and paint for preliminary screening and to help determine the course of subsequent action.

Checklist of equipment, materials and accessories

- Reagents for the various types of spot tests

  for drugs and precursors

  for explosives

  for biological material

  for GSR

  Spot plates

- Pipettes, droppers

In addition for GSR

- Very porous paper (e.g. large sheets of blotting paper) or gelatine-coated photographic paper

Hot press/iron

Related skills requirements

Knowledge of the principle and use of colour, luminescence and solubility reactions.

Awareness of their presumptive nature as well as their limitations (e.g. lack of specificity, mediocre sensitivity, possibility of false positives and negatives).

Ability to prepare spot test reagents and to use these reagents to test for the presence of target substances (e.g. common illicit drugs).

Awareness of the need to test positive and negative controls at the same time as the questioned material.

Ability to interpret the pattern of GSR deposits on targets and knowledge of the limitations (e.g. results specific to a particular firearms and ammunition combination).

D. Microscopy techniques

(a) General microscopy techniques

(Stereomicroscopy, brightfield microscopy, polarized light microscopy, incident light comparison microscopy, transmitted light comparison microscopy)

Stereomicroscopy provides magnifying powers lower than standard microscopes and presents the advantage of offering a 3D image of an object. It is typically used in forensic science to examine the structure of physical evidence that does not require very high magnifications (e.g., tool marks, projectiles, questioned documents, general botanical features such as Cannabis trichomes, biological cells) and/or as a primary tool to characterize physical evidence (e.g., paint, fibres, gunshot residues, biological cells, in particular spermatozoa). The stereomicroscope is the most frequently used magnification system found in a forensic laboratory.

Checklist of equipment, materials and accessories

Stereomicroscope, including:

Document stage and fibre optic illumination, transmitted/reflected light, annular and coaxial light, replacement lamps

Scale standards for measurements

Digital camera compatible with the various microscopes in the laboratory, including computer and software

The brightfield microscope's higher magnifying power is indispensable for finding and characterizing microtrace evidence (e.g. individual textile fibres, hairs, spermatozoa, etc.).

Checklist of equipment, materials and accessories

Brightfield microscope, including:

Transmitted/reflected light, polarizing filters, replacement lamps

Scale standards for measurements

Digital camera compatible with the various microscopes in the laboratory, including computer and software

¤ Glass microscope slides, approx. 76x26 mm

¤ Cover slips, 18x18 mm

¤ Selection of temporary and permanent mountants

Comparison microscopy involves the use of two compound microscopes that are linked by an optical bridge to permit the simultaneous viewing, via a single set of eyepieces, of the two independent images (from two independent specimens). The optical bridge will generally provide a split screen (with a variable demarcation line) to view the images side-by-side, and the possibility of superimposing the two images.

Incident light comparison microscopy (also known as reflected or episcopic) permits the visualization of two samples using reflected light illumination, with this system being applied to the comparison of tool marks on projectiles and cartridge cases, ink lines on documents, as well as paint chip cross-sections (where the samples have been prepared for reflected light microscopy).

Checklist of equipment, materials and accessories

* Incident light comparison microscope, including:

Illumination including UV, fibre optics, replacement lamps

Supports for projectiles, cartridge cases and documents

Scale standards and optical micrometers for measurements

Digital camera compatible with the various microscopes in the laboratory, including computer and software

A *transmitted light comparison microscope* is considered an essential tool for the comparison of hairs and fibres. When thin paint cross-sections have been prepared (e.g., using a microtome), then these may also be examined using a transmitted light comparison microscope.

Checklist of equipment, materials and accessories

* Transmitted light comparison microscope, including:

Transmitted/reflected light, polarizing filters, replacement lamps

Scale standards for measurements

Digital camera compatible with the various microscopes in the laboratory, including computer and software

- ¤ Glass microscope slides, approx. 76x26 mm
- ¤ Cover slips, 18x18 mm
- ¤ Selection of temporary and permanent mountants

Polarized light microscopy is a powerful technique that can be used to determine how a particular material behaves when subjected to polarized light. "Isotropic" materials are not affected by polarized light whereas "anisotropic" materials have optical properties that vary depending on the orientation of the incoming light. Interference colours are observed for any anisotropic specimen under examination through crossed polarizing filters, with this colour being representative of the sample's chemical composition. As such, a polarizing light microscope can provide information on the identity of a wide range of trace materials including textile fibres and microcrystals (e.g. those formed on slide through a chemical reaction between an illicit drug and a microcrystal reagent). The technique can also be used to confirm the presence of glass fragments as such fragments are isotropic and therefore show no interference colours when viewed through crossed polarizing filters.

Checklist of equipment, materials and accessories

Polarizing light microscope, including:

Transmitted light, polarizing filters, replacement lamps

Scale standards for measurements

Digital camera compatible with the various microscopes in the laboratory, including computer and software

- ¤ Glass microscope slides, approx. 76x26 mm
- ¤ Cover slips, 18x18 mm
- ¤ Selection of temporary and permanent mountants

Related skills requirements

Knowledge of the principles of microscopy, including polarized light microscopy and stereomicroscopy, and the various applications depending on the physical evidence and the purpose of the examination.

Knowledge of the various illumination techniques and their characteristics to show and measure properties of the physical evidence.

Ability to prepare quality microscopy slides (without air bubbles) to ensure optimum observation conditions.

Ability to correctly set up a microscope before use (e.g., Köhler illumination).

Ability to use microscopy techniques to allow measurements and optimal observation of physical evidence of interest (e.g., drugs, paint, hair, fibres, glass, fired ammunition, inks, etc.).

(b) Hot stage techniques (melting point and glass refractive index measurements)

Melting point

The melting point of a chemical compound can be used to assist in the identification of that compound. Within the forensic arena, melting point may assist in the identification of synthetic fibres and pure drug samples (e.g. drug reference material). Melting point is an unreliable indicator when chemical mixtures are encountered.

Checklist of equipment, materials and accessories

Melting point apparatus (e.g., hot stage microscope), with a temperature range of 50–350ºC, with a minimum temperature increase rate of 2ºC/min

Microscope with binocular tube (10x), 10x/0.25 objective, magnification 100x (e.g., Leica, ThermoGalen)

Pre-centred condenser with aperture iris diaphragm

Source of illumination, e.g., 20W tungsten halogen illumination

Thermometers operating over different temperature ranges

Related skills requirements

Adequate practice in the determination of melting points and mixed melting points as an initial indication of sample purity using known samples and mixtures of known samples.

Glass refractive index measurement

Glass particles are immersed in a liquid medium whose refractive index (RI) is calibrated as a function of temperature. The temperature is increased using a hot stage until the refractive index of the glass particle equals that of the liquid (indicated by the disappearance of the Becke line), allowing the determination of the RI of the glass. An automated approach for measuring the RI of glass fragments is available with the instrument known as the GRIM (Glass Refractive Index Measurement; Foster and Freeman).

Checklist of equipment, materials and accessories

Equipment

* * Refractive index measurement system: heating stage with a microscope (GRIM; Glass Refractive Index Measurement)

Materials and accessories

¤ Silicone oils of known refractive index characteristics

Glass standards of known refractive indices

¤ Glass microscope slides, approx. 76x26 mm

¤ Cover slips 18x18 mm

Monochromatic light (white light with suitable interference filter)

Related skills requirements

In addition to skills for microscopy:

Theoretical

Knowledge of phase contrast optics

Knowledge of glass chemical composition and physical characteristics

Knowledge of the Becke Line phenomenon (bright halo that is observed near the edge of a particle when it is immersed in a liquid of different refractive index)

Experimental

Ability to prepare microscopy slides with appropriate sample and mounting medium (silicone oil)

Ability to operate the apparatus and make accurate measurements

(c) Scanning electron microscopy

A scanning electron microscope (SEM), using a beam of electrons and electromagnetic lenses, can achieve magnification over a range from approximately 10x to more than 200,000x. For forensic applications, magnifications up to 5,000x are typically employed. If the SEM is fitted with an energy-dispersive X-ray (EDX) analyser, then this X-ray emission can be captured and interpreted to provide an elemental profile of the sample. SEM-EDX is a very powerful analytical technique for forensic applications (such as the analysis of gunshot residues) as it permits the study of both morphology and chemical composition for extremely small particles (see section *(e)* on page 95 for the related technique of X-ray fluorescence).

Checklist of equipment, materials and accessories

* Scanning electron microscope (SEM), preferably fitted with an energy-dispersive X-ray (EDX) analyser

Equipment required for sample preparation prior to SEM-EDX analysis

Range of elemental standards relevant to the evidence types being analysed

Related skills requirements

Knowledge of SEM imaging principles

Knowledge of X-ray emission phenomena and how emission spectra can be used to obtain elemental information

Ability to prepare samples for SEM-EDX analysis

Ability to operate the instrument and obtain optimum imaging and EDX results

E. Chromatographic techniques

(a) Capillary electrophoresis

Electrophoresis is the migration of charged species in a solution under the influence of an electric field. Different species with different charges and/or sizes migrate with different velocities. Capillary electrophoresis (CE) is a collective term for a number of electrophoretic separation techniques (capillary zone electrophoresis (CZE), capillary isotachophoresis (CITP), capillary gel electrophoresis (CGE), capillary isoelectric focussing (CIEF), micellar electrokinetic capillary electrochromatography (MECC, MEKC) and capillary electrochromatography (CEC). All sub-techniques can be carried out with the same instrument; the difference is determined by the choice of separation media and capillary. In CE, the separation of the analytes is performed in quartz capillaries with internal diameters ranging from 25 to 100μm. The ends of the capillaries are connected to two electrodes: a positive electrode and a negative electrode, which are connected to a power supply. The capillary is filled with a background electrolyte (BGE) and the sample is introduced by either pressure or voltage. A voltage is subsequently applied to effect the separation of the analytes.

Applications include the analysis of illicit drugs (in seized samples or in biological samples) and explosives (e.g. analysis of anions and cations in improvised explosive mixtures).

Checklist of equipment, materials and accessories

Capillary electrophoresis equipment with a suitable detector, typically UV/VIS, fluorescence and/or mass spectrometer.

¤ Capillaries (The choice depends on the specific application and could be unmodified fused silica, permanently or dynamically modified inner silica surface, organic polymeric materials or packed capillaries for CEC)

¤ Replacement lamp (for UV/VIS and fluorescence)

¤ Electrophoresis-grade chemicals and solvents

¤ Range of buffers and/or additives for specific applications

¤ Sample vials/well-plates (depending on instrument and application)

Vial racks

¤ Reference standards

Related skills requirements

Knowledge of the theory and mechanism of CE including understanding of the concepts of pH, pKa and ionization, electro-osmotic flow and electro-migration of ions.

Awareness of the various instrumental components, such as pump, injection system, fused silica column, and the various possible detector systems, and their functions.

Awareness of the effect of buffers, BGE additives, temperature and viscosity on the electrophoretic mobility of charged species.

Awareness of the causes of, and solutions to common operation problems (e.g. buffer depletion, zone broadening, thermal management, resolution).

Knowledge of concept of quality assurance and method validation.

Ability to use CE equipment and to perform operational procedures and simple troubleshooting.

Ability to design experiments aimed at selecting operating conditions for optimum resolution, efficiency and selectivity (capillary pre-treatment/conditioning, buffer type and pH, sample introduction mode, operating voltage and detection mode).

Interpretation of electropherograms; Qualitative and qualitative application of electrophoretic data.

Experience in quantitative analysis.

(b) Gas chromatography

Gas chromatography—flame ionization detector/mass spectrometry/ other detectors (e.g., nitrogen-phosphorous detector, electron capture detector)

Gas-liquid chromatography (generally referred to as gas chromatography or GC) is one of the most versatile and commonly used forms of chromatography in forensic chemistry. The mobile phase is an inert gas (typically helium, nitrogen or hydrogen), while the stationary phase is a very viscous, high-boiling liquid. Many different GC detectors are available, some that are non-specific (i.e. produce a signal for a wide range of different compounds, such as the flame ionization detector, or FID), some that are specific to substances that have certain chemical properties (e.g. nitrogen-phosphorus detector, or NPD; or electron-capture detector, or ECD, for analysis of halogen-containing substances), and some that provide not only a signal but also a spectrum of each sample component (e.g. mass spectrum or infrared spectrum). GC separation techniques are commonly employed for the analysis of illicit drugs (in seized material or in biological specimens such as blood or urine), explosives, and ignitable liquid residues (as may be present in fire debris samples), which are sufficiently volatile and do not decompose at the GC typical temperature (usually below 400°C).

Gas chromatography in combination with a mass spectrometer as detector unifies the separation power and sensitivity of a GC-FID with the analyte specificity of a spectroscopic technique, providing highly specific spectral data on individual compounds in a complex mixture of compounds without a prior separation step.

Checklist of equipment, materials and accessories

Equipment

* Gas chromatograph equipped with a suitable detector (e.g. FID, NPD, ECD)

Auto sampler

Special gases facilities (gas cylinders or gas generator, valves, tubes) for air, H2 and/ or N2

Data processing facilities

Materials and accessories

Crimp sealer

Decapper

Stainless steel tweezers

Wrenches

Vial racks

¤ GC capillary column (e.g. DB-5®, 20 to 30 m × 0.2 or 0.25 mm i.d., 5 per cent-phenyl–95 per cent-dimethyl-polysiloxane with 0.25 to 1 µm film thickness)

¤ Graphite ferrules

¤ Split/splitless injector liners

¤ Inlet septa

¤ Nuts

¤ Syringes, 10 µl (for manual injection and auto sampler)

¤ Glass vials

¤ High purity (5.0) gases (H2 or N2 as carrier; H2 and air for FID)

¤ Vial caps and septa

¤ Screw caps

¤ Derivatization reagents (e.g., MSTFA, BSTFA, TMCS)—optional

Hot plate/heat block or water bath to warm-up vials for headspace analyses.

Capillary column cutter

¤ Reference/standard substances and test mixtures (e.g. Grob mixture; test mixture for Kovats' index)

Additional equipment, materials and accessories related to the use of a mass spectrometry (MS) detector

* Gas chromatograph equipped with a mass spectrometer as a detection system

* Vacuum pump with basic maintenance kit (e.g., oil, spare o-rings)

¤ High purity gases (5.0) (helium as carrier)

Reference libraries and search/compare software

MS tune reagent

Spare MS filaments

MS maintenance kit

Related skills requirements

Theoretical

Knowledge of the theory and mechanism of separation, including the properties and the role of the stationary and mobile phases.

Knowledge of the various instrumental components (injection port, column, oven, detector) and their functions.

Awareness of common operational problems and their possible causes (e.g. peak tailing, appearance of spikes, loss of sensitivity, longer retention times, etc.).

Ability to design a calibration experiment for quantitative analyses (internal and/or external standard methods)

Knowledge of concept of quality assurance and method validation

Experimental

Ability to prepare samples and avoid cross contamination

Ability to use and maintain the instrumentation and follow operational procedures; ability to determine conditions for optimum separation and detector response (e.g., type of column, temperature of the injector, oven and detector, the flow rate of the carrier gas), as well as to value the significance of retention time.

Adequate practice in the application of GC methodology; ability to design experiments using temperature programming and, where appropriate, derivatization techniques to separate peaks otherwise not satisfactorily resolved.

General knowledge of columns (packed and capillary) and of the criteria for the choice of a suitable column; familiarity with various types of stationary phases available (e.g. DB-1, DB-5, OV-17… or equivalent) and their uses; ability to screen stationary phases suitable for various routine applications.

Experience in quantitative analysis using, inter alia, the internal standard method; ability to evaluate appropriate internal standards for the quantitative assaying of various compounds, taking into consideration availability, safety, health hazard and cost.

Additional skills related to the use of mass spectrometer as detector

Theoretical

Knowledge of the theory and mechanism of mass spectrometry, including the common approaches for ionization of compounds present in the gas stream and separated in the GC column

Knowledge of the various instrumental components (ion source, mass analyzer, pumping systems) and with their functions.

Awareness of the interface between mass spectrometry and gas chromatography, and the value of mass spectrometry as a compound identification technique.

Knowledge of the fragmentation process (and the mass-to-charge ratios of fragment ions).

Experimental

Ability to use and maintain the instrumentation and operational procedures related to the mass spectrometer.

Ability to properly interpret mass spectra, including the use of relevant spectral libraries.

Pyrolysis-GC (all detectors)

Pyrolysis gas chromatography (pyrolysis-GC; or Py-GC) is an analytical method used for the analysis of materials that are not sufficiently volatile to be analysed by direct gas chromatography. Py-GC involves the use of a pyrolysis probe that is directly inserted into the injector of the gas chromatograph. A small quantity of the material of interest is placed on the heating element of the probe prior to its insertion in the GC. After equilibration in the injector, the pyrolyser is turned on, resulting in the sample being rapidly heated to a set temperature that is generally within the range 700–1000º C. Sample decomposition occurs and the pyrolysates are swept into the GC column by the flow of inert carrier gas. The volatile fragments are then separated and detected as for conventional GC analysis, resulting in a pyrogram. Py-GC in combination with a mass spectrometer as detector (i.e. Py-GC-MS) is a powerful analytical method for the forensic analysis of various polymeric materials including textile fibres and paint samples.

Additional equipment, materials and accessories

* Pyrolysis equipment compatible with GC equipment
¤ Sample probes
¤ Spare tubes

Additional skills related to the use of a pyrolyzer (including sample preparation)

Knowledge of the theory and mechanism pyrolysis, including the common techniques for sample preparation.

Ability to use the instrumentation and operational procedures related to pyrolysis coupled with gas chromatography.

Ability to properly interpret the chromatogram (pyrogram) obtained by GC.

Headspace – GC (all detectors)

When a sample such as fire debris or an illicit drug is kept within an enclosed container, the "headspace" (or air space) above the sample will contain a certain concentration of any volatile compounds present within the sample. This concentration can be increased by heating the container. A vapour sample can be collected using a gas-tight syringe and this sample analysed by gas chromatography. This constitutes the analytical technique known as headspace-GC, which can be applied to the analysis of samples including fire debris (for the detection of ignitable liquid residues) and illicit drugs (for the detection of solvent residues). As an alternative to direct headspace sampling, an adsorbent material (e.g. activated charcoal) can be exposed to the headspace to concentrate any volatile compounds that may be present. This concentration technique can be "dynamic" if the headspace vapour passes over or through the adsorbent, or "passive" if no headspace vapour movement is involved.

Solid phase-micro extraction (SPME) is an example of a passive headspace sampling technique.

Additional equipment, materials and accessories

* Headspace sampler compatible with GC equipment

¤ Sample vials

¤ Vial caps and septa

Crimp seal

Decapper

Additional skills related to the use of headspace (including sample preparation)

Knowledge of the theory of headspace analysis, including the common techniques for sample preparation.

Ability to use the instrumentation and operational procedures related to headspace analysis coupled with gas chromatography.

Ability to properly interpret chromatogram obtained by headspace-GC.

(c) High performance-liquid chromatography (HPLC)

Liquid chromatography (LC) is a separation technique in which the mobile phase is a liquid. One of the simplest forms of liquid chromatography is to dissolve the sample in a suitable solvent and run the solution through a column of silica gel as the stationary phase. The process is relatively slow as it relies on gravity to move the mobile phase through the chromatographic column. Modern LC systems use a very fine, tightly packed stationary phase with a pump employed to force the mobile phase through the column under pressure. This significantly increases the speed of separation while retaining a very high resolving power. Such systems are referred to as high performance (or high pressure) liquid chromatography (HPLC). When the stationary phase is more polar than the mobile phase (e.g. toluene as the mobile phase and silica gel as the stationary phase), the technique is referred to as normal-phase liquid chromatography (NPLC). When the mobile phase is more polar than the stationary phase (e.g. water-methanol mixture as the mobile phase and C18 octadecyl as the stationary phase), the technique is referred to as reverse-phase liquid chromatography (RPLC). RPLC is the most commonly used form of HPLC for forensic applications. Various detection systems are possible including fixed-wavelength detection (eg. UV), diode-array detectors (DAD), electrochemical (EC) detectors, and mass spectrometry (MS) detectors.

Common HPLC applications include illicit drugs (in sized materials and in biological specimens), explosives, and dyes (e.g. in writing inks and textile fibres).

Checklist of equipment, materials and accessories

Equipment

* High performance liquid chromatograph equipped with a UV detector or a mass spectrometer (or other detection system such as DAD, electrochemical)
* Autosampler

Material and accessories

¤ Suitable HPLC columns

¤ Solvents

Stainless steel tweezers

Wrenches

Vial racks

¤ Septa

¤ Nuts

¤ Syringes, 10-20 µl (for manual injection and auto sampler)

¤ Syringes, 1-3 ml (for sample filtration)

¤ Syringes filters with the adequate membranes (e.g. 30mm diameter, membrane PTFE, porosity 0.20µm)

¤ Glass vials

¤ Vial caps and septa

¤ Screw caps

¤ Reference/standard substances

Related skills requirements

Theoretical

Knowledge of the theory and mechanism of HPLC separation, including the properties and the role of the stationary and mobile phases.

Awareness of the various instrumental components, including the pump or solvent delivery system, the injection system, the separation column, and the various detection systems, and their functions.

Knowledge of the importance of mobile phase composition (i.e., solvent specifications).

Awareness of factors affecting sensitivity, for instance the composition of the mobile phase.

Knowledge of the different column specifications and of the criteria for the choice of a suitable column; familiarity with various types of phases available (e.g. reverse phase, normal phase) and their uses; ability to screen phases for various applications.

Awareness of common operational problems (e.g. peak tailing, appearance of spikes, loss of sensitivity, longer retention times, interferences) and knowing how to address them

Knowledge of quality assurance and method validation requirements.

Experimental

Ability to use HPLC equipment and associated operating procedures.

Ability to determine conditions for optimum separation and detector response, keeping in mind the significance of retention time.

Ability to design experiments aimed at selecting operating conditions for optimum separation of sample components and optimum detector response (e.g. type of column phase, mobile phase composition and parameters), as well as to value the significance of retention time.

Experience in quantitative analysis using, inter alia, the internal standard method.

Ability to evaluate appropriate internal standards for the quantitative assaying of various compounds, taking into consideration ready availability, safety, health hazard and cost.

Ability to setup experiments with the various detector systems and understand the results and limitations of the experiments.

(d) Ion chromatography

Ion-exchange chromatography (or ion chromatography; IC) is a form of liquid chromatography that permits the separation of ions and polar molecules based on the charge properties of the analytes. Conventional IC uses a stationary phase composed of an ion exchange resin that carries charged functional groups that interact with oppositely charged groups of the compounds to be analysed. Its greatest utility is for the analysis of anions for which there are only limited analytical methods available. It is also commonly used for cations and biochemical species such as amino acids and proteins. Most ion-exchange separations are done with pumping systems and injector/column/detector configurations that are similar to conventional HPLC. In general, ion chromatography is one of the more difficult types of liquid chromatography to exploit. Applications include the analysis of various inorganic cutting agents in illicit drugs, and the identification of inorganic compounds used in improvised explosive mixtures.

Checklist of equipment, materials and accessories

* Ion chromatography equipped with a suitable detector (such as conductivity, amperometric UV/VIS detection)
* Auto sampler

Material and accessories

¤ Suitable IC columns and pre-columns (guard columns)

¤ Deionized water

¤ Specific reagents (e.g. sulphuric, oxalic, nitric acids, sodium carbonates and bicarbonates)

¤ Syringes, 1-3 ml (for sample filtration)

¤ Syringes filters with the adequate membranes (e.g. 30mm diameter, membrane PTFE, porosity 0.45 µm)

Vial racks

¤ Glass Vials

¤ Vial caps and septa

¤ Screw caps

¤ Reference/standard substances

Related skills requirements

Theoretical

Knowledge of the theory and mechanism of IC, including the properties and role of separation column and suppressor device.

Awareness of the various instrumental components, such as pump, injection system, separation column, and the various possible detector systems, and their functions.

Knowledge of different columns and of the criteria for the choice of a suitable column.

Awareness of common operational problems (i.e., loss of sensitivity, longer retention times, interferences).

Knowledge of concept of quality assurance and method validation.

Awareness of the possibility to use a suppressor system as part of the detection unit to chemically reduce the high background conductivity of the electrolytes in the eluant, and to convert the sample ions into a more conductive form.

Experimental

Ability to use IC equipment and to perform operational procedures.

Ability to design experiments aimed at selecting operating conditions for optimum separation of sample components and optimum detector response (e.g. type of column phase, mobile phase composition and parameters), as well as to value the significance of retention time.

Experience in quantitative analysis.

Ability to setup experiments with the various detector systems and understand the results and limits.

(e) Thin-layer chromatography

Thin-layer chromatography (TLC) is one of the simplest and oldest forms of chromatography that uses a solid stationary phase and a liquid mobile phase. It can be employed as a screening technique, for the presumptive identification of a target substance (e.g. illicit drug or explosive), or for sample comparison (e.g. dyes extracted from textile fibres or writing inks). While it lacks the sensitivity and resolving power of more sophisticated analytical separation techniques, it has application because of its ease of use, portability and flexibility in both the stationary and the mobile phase, making it amenable to a wide range of substances, ranging from the most polar to the most non-polar materials. It is also amenable to a variety of visualization techniques, and it is inexpensive.

High–performance TLC (HPTLC) is characterized by the use of kinetically optimized layers, specific instrumentation for automated sample application, development and detection and can lead to faster and more efficient separations that provide accurate and precise quantitative results.

Checklist of equipment, materials and accessories

Equipment

TLC spray box (a cardboard box can be used)

Developing tanks

Atomizers with rubber bellows for spray reagents

Air blower (to dry plates after sample application or after development)

Ultraviolet lamp (254 and 366 nm)

Desiccator for TLC plate storage

Materials and accessories

¤ Solvents

¤ Spray reagents (colour reagents/iodine vapors)

¤ Glass or aluminium silica gel coated plates (20x20, 20x10, 20x5 cm), with and without fluorescent indicator (alumina and other adsorbent layers are also possible depending on the application)

¤ Glass micro capillary tubes, 2 µl

¤ Filter paper (for development chamber saturation)

Multipurpose spotting guide, 20x20 cm

Reference standards (known compounds) and Rf database

¤ TLC plate heater

If no commercial silica gel plates are available[17]

Spreading table with levelling device

TLC plate coater

Drying and/or storage rack for 20x20, 20x10 and 20x5 cm TLC plates (temperature range 40-250°C)

¤ Glass plates 20x20, 20x10, 20x5 cm (approx. 4mm thickness)

¤ Silica gel with and without fluorescent indicator (and/or alumina or other adsorbents)

[17] Commercial silica gel plates are recommended for most applications. Nevertheless, if the laboratory has the equipment and experience to produce home-made TLC plates, there is no reason to discontinue this approach.

Related skills requirements

Theoretical

Knowledge of the principles of TLC separation.

Awareness of the factors that affect separation, including the influence of water content on the stationary phase, the saturation of the development chamber, the amount of sample spotted, sample impurities, and operating conditions (including eluent composition).

Knowledge of the eluotropic series and of the general criteria for the selection of appropriate solvent systems.

Knowledge of the significance of Rf values.

Knowledge of various visualization spray reagents for different applications.

Ability to prepare and apply visualization reagents yielding clearly defined spots and stable colours, thus allowing the accurate determination of Rf values and, by comparison with reference substances, positive compound identifications.

Awareness of possible chromatographic problems (e.g. distorted solvent front, undermigration, overmigration, etc.) and likely causes/solutions.

Experimental

Ability to use TLC equipment and associated operating procedures; extensive practice in proper spotting techniques, plate introduction into developing tanks and plate preparation for visualization; experience in plate evaluation as to sensitivity and specificity; ability to resolve issues such as spot overlapping and tailing.

Ability to compare suitable solvent systems and to select systems for optimum separation; experience in the preparation and evaluation of solvent systems by varying the nature, number and proportion of their components in order to obtain the best possible chromatographic resolution.

Ability to design and use multi-development and two-dimensional TLC experiments aimed at improving the separation of substances that are otherwise too close to each other when only one-dimensional and single-development TLC is used.

Practice in the use of high-performance TLC (HPTLC).

Experience with preparative techniques used to isolate discrete amounts of substances from such plates and work-up procedures to isolate samples components for confirmatory analyses.

Ability to prepare and activate TLC plates based on silica gel or other adsorbents (with or without fluorescent indicator), as well as an ability to test such plates for the effective separation and positive identification of as many sample components as possible.

F. Spectroscopic/spectrophotometric techniques

(a) Fourier-transform infrared spectroscopy

When infra-red (IR) radiation of the proper energy strikes a molecule, absorption will occur and chemical bonds within the molecule will start to vibrate. Each different bond within a molecule will have its own characteristic vibration frequency, and an arrangement of bonded atoms can undergo a number of different kinds of vibrations. As a result, a given molecule will have many infrared absorptions and even a slight change in the structure or composition of the molecule will result in significant differences in the IR absorption spectrum. The mid-IR spectrum is considered to be the 'chemical fingerprint' of a substance, and the range from 2000 to 400 cm-1 often referred to as the 'fingerprint region'. As such, infrared spectroscopy is a powerful technique for the comparison and identification of various samples, including illicit drugs, explosives, photocopy toners, textile fibres, and paints. Instruments range from large bench-top systems fitted with infrared microscopes, through to portable devices for on-site analyses.

Fourier-Transform Infrared (FTIR) spectroscopy is a variant of infrared spectroscopy that uses an interferometer to simultaneously collect all frequencies and a mathematical technique known as Fourier transform to convert the resulting signal into a spectrum similar to that from conventional (dispersive) infrared spectroscopy. FTIR is characterized by significantly reduced measurement times and an improved signal-to-noise ratio and sensitivity. Because of its various advantages, virtually all modern infrared spectrometers are FTIR instruments.

Checklist of equipment, materials and accessories

Equipment

* Infrared spectrometer including computer and softwares [e.g. Fourier-Transform Infrared equipment]

Infrared microscope—optional

Reference libraries and search/compare softwares

Manual hydraulic press (15 tonnes)—for use in the halide disc method, i.e. the sample is dispersed into finely ground potassium halide (KBr or KCl) and pressed into a thin disc

Materials and accessories

Sampling accessories (e.g. diamond compression cell, ATR accessory)

KBr die (e.g., 13 mm diameter)—for use in halide disc method

Micro KBr die (e.g., 1.5-3 mm diameter)—for use in halide disc method

Sample holder

Demountable cell mounts

Agate mortar (e.g., 35 mm diameter) and pestle - for use in halide disc method

KBr/NaCl windows

Teflon spacers

Stoppers

- ¤ Paper rings (e.g., for 13 mm die)—for use in halide disc method
- ¤ Syringe, 2 ml—for use in Nujol mull method
- ¤ Nujol—for use in Nujol mull method
- ¤ Fluorolube
- ¤ KBr powder—for use in halide disc method
- ¤ Liquid nitrogen for MCT detectors

Related skills requirements

Theoretical

Knowledge of the theory and mechanism of absorption of infrared radiation frequencies and their conversion by organic molecules into rotational and vibrational energies.

Knowledge of the infrared range within the electromagnetic spectrum, wavelength-frequency and wavelength-wave number relationship.

Awareness of the requirements for absorption and the number of fundamental vibrational modes for linear and non-linear molecules; understanding of the factors limiting or increasing the number of observed absorption bands and of frequency changes due to the molecular environment.

Knowledge of the characteristic infrared group frequencies and ability to draw structure-spectra correlations.

Knowledge of the laws of light absorption; ability to make absorbance measurements and to establish calibration curves for quantitative analyses.

Knowledge of alternative sampling techniques (ATR, gaseous, DRIFTS).

Experimental

Ability to use the instrumentation and associated operating procedures.

Ability to select operating parameters for best results, including background, gain, slit width and scanning speed; basic understanding of the effects of such parameters on spectra.

Ability to prepare and handle liquid, mull and KBr disc samples; experience in quantitative IR analysis.

Ability to prepare samples (e.g. textile fibres and paint chips) for direct analysis using an infrared microscope.

(b) Ion mobility spectrometry

Ion mobility spectrometry (IMS) is a gas-phase form of electrophoresis that has become a common technology used in field-portable systems (both bench-top and hand-held) for the detection of illicit drugs and explosives. The separation principle in IMS relies upon the differential migration of gas phase ions through a uniform electric field. In a typical IMS device, the gas sample (either a direct air sample or vapour produced by heating particles on a cloth swab or filter) is ionized by exposure to a radioactive source (generally a beta emitter such as 63Ni). In the ionization chamber of the IMS, drug samples generate positive ions while common explosive compounds generate negative ions. The ionized material enters a "drift tube" and moves towards a collector electrode under the influence of a uniform electric field. Ions are recorded at the detector in order from the fastest to the slowest, generating a response signal that is a representation of the chemical composition of the measured sample. The IMS technique is extremely sensitive, with detection limits in the order of nanograms (ng) for illicit drugs and picograms (pg) for explosives. Mobility spectra (also known as plasmagrams), however, are relatively information-poor to the extent that a positive IMS response for a particular target compound (e.g. explosive or illicit drug) is considered a presumptive indicator only for the presence of that compound.

Checklist of equipment, materials and accessories

Equipment

* Ion mobility spectrometer

Laptop

Materials and accessories

Trolley (for bench-top units)

Vacuum sampler

Vacuum sampling nozzles

Calibration standards

Extension cable

¤ Teflon filter disks, diameter 0.45 µm

¤ Falcon tubes 15 ml

¤ Cloth swabs

Related skills requirements

Theoretical

Knowledge of ion mobility spectrometry, including the operating principle, detection limits, and plasmagram analysis.

Knowledge of thermal desorption principles.

Knowledge of applications and limitations of the technique.

Knowledge of sensitivity and contamination risks.

Experimental

Ability to use the instrumentation and associated operating procedures.

Practice in the application of IMS methodology, including collection of evidence at the crime scene (e.g., one sample for direct analysis and one for separate gas chromatography analysis to confirm any positive results obtained by ion mobility spectrometry).

(c) Micro-spectrophotometry

Micro-spectrophotometry is used for an objective comparison of colour based on the measurement of absorption spectra in the visible light range. The technique can be applied to a range of coloured samples including textile fibres, paint, inks on paper, and coloured glass fragments.

Checklist of equipment, materials and accessories

Equipment

* Micro-spectrophotometer (covering at least the visible range from 380 to 780 nm)

Computer

Software for instrument control, data recording, and data analysis

Materials and accessories for fibre analyses

¤ Microscope slides and cover slips (for short-wave UV measurements, quartz slides and cover slips are required)

¤ Suitable mountants

Related skills requirements

Knowledge of the theory and mechanism of light absorption and reflection

Awareness of the effect of the homogeneity of the sample on the spectra

Awareness of the importance of establishing inter-/intra-sample variability

Ability to select an appropriate measurement window

Ability to interpret absorption spectra and to determine if samples can be differentiated based on observed spectral differences

(d) Raman spectroscopy

Raman spectroscopy is another vibrational technique and is complementary to infrared spectroscopy. While results also depend on the vibrations that bonds undergo within a molecule, it is scattered radiation rather than absorbed radiation that is studied. Radiation from an intense monochromatic light source, typically a laser, is directed on the sample and the scattered radiation collected and analysed. Most of the photons will be scattered at the same wavelength—this is elastic scattering known as Rayleigh scattering. However, a small fraction of the scattered photons will exhibit wavelength shifts due to inelastic—or Raman—scattering. The energy of these scattered photons can be greater than or less than that of the incident radiation. The challenge with Raman spectroscopy is the separation and analysis of the very weak inelastically scattered light from the intense background of Rayleigh scattered radiation. Raman instruments range from large bench-top systems to portable (even hand-held) devices for on-site analyses. Applications include the comparison and identification of illicit drugs, explosives, writing inks, textile fibres and paint.

Checklist of equipment, materials and accessories

* Raman spectrophotometer including computer and softwares [e.g. Fourier Transform Raman equipment]

Reference libraries and search/compare softwares

Materials and accessories

Spatulas, assorted

Scissors

¤ Tweezers and disposable tweezers, assorted

¤ Scalpels and disposable scalpels, round and pointed blades (and replacement blades)

Related skills requirements

Theoretical

Knowledge of the theory and mechanism of light scattering and the Raman effect.

Knowledge of the Raman range within the electromagnetic spectrum.

Knowledge of the characteristic Raman group frequencies and ability to draw structure-spectra correlations.

Experimental

Ability to use the instrumentation and operational procedures.

Ability to select operating parameters for best results, including background, gain, slit width and scanning speed; basic understanding of the effects of such parameters on spectra.

Ability to prepare and handle samples.

(e) X-ray fluorescence

X-ray fluorescence (XRF) involves the detection of the characteristic X-rays that are emitted by a sample following X-ray excitation. XRF analysis provides both qualitative (i.e. what elements are present in a sample) and quantitative information (i.e. relative concentrations of each element), as the intensity of each characteristic emission is directly related to the amount of each element in the material. Analyses are non-destructive, and limits of detection down to ppm levels can generally be achieved for most elements. For forensic applications, several instrument manufacturers produce X-ray microfluorescence (micro-XRF) spectrometers that use collimators or capillary optics to achieve X-ray beam diameters down to around 10 μm. With such systems, it is possible to obtain XRF spectra on single fibres, paint chips and glass fragments.

A scanning electron microscope fitted with an energy-dispersive X-ray spectrometer (SEM-EDX) can also be used to obtain the elemental profile of a sample (see section *(c)* on page 76). In this case, it is a high-energy electron beam, rather than X-rays, that create inner-shell ionizations in sample atoms. The characteristic X-ray emissions are the same as for XRF. SEM-EDX tends to be more effective for lighter elements, while XRF shows better sensitivity for heavier elements. The use of an SEM-EDX is considered routine for the detection and identification of individual gunshot residue (GSR) particles.

Checklist of equipment, materials and accessories

Equipment

* X-ray fluorescence (XRF) spectrometer including computer and softwares

Materials and accessories

Spatulas, assorted

Scissors

¤ Tweezers and disposable tweezers, assorted

¤ Scalpels and disposable scalpels, round and pointed blades (and replacement blades)

Related skills requirements

Theoretical

Knowledge of the theory and mechanism of X-ray fluorescence (XRF) to qualitative and quantitative elemental analysis.

Experimental

Ability to use the instrumentation and operational procedures.

Ability to prepare and handle samples.

(f) Ultraviolet-visible spectrophotometry

Ultraviolet-visible spectroscopy or ultraviolet-visible spectrophotometry uses light in the ultraviolet-visible (UV/VIS) region of the electromagnetic spectrum and involves the measurement of light absorbance (A) as a function of wavelength (λ). Beer's Law states that the absorption of light (A) at a particular frequency is directly proportional to the concentration (c) of the absorbing species. UV-visible spectrophotometry can therefore be used as a technique for quantification. Applications include the quantitative analysis of illicit drugs in seized materials and in biological specimens.

Checklist of equipment, materials and accessories

Equipment

* Ultraviolet-visible spectrophotometer, including:

double beam optics; wavelength range 190-900nm; spectral bandwidth: 2nm; variable scan speeds; computer and software

Materials and accessories

Tungsten replacement lamp

Deuterium replacement lamp

Standard quartz cells

¤ Spectroscopy-grade solvents

Related skills requirements

Theoretical

Knowledge of the theory and mechanism of molecular light absorption and electronic transitions; awareness of the electromagnetic spectrum and the definition and nature of electromagnetic radiation.

Knowledge of wave properties of radiation, wavelength-frequency relationship and radiation energy.

Knowledge of molecular energy states (vibrational, rotational and electronic) and molecular energy changes.

Awareness of chromophores, auxochromes and conjugation, and their effects on spectra.

Awareness of the effects of solvent and pH on wavelength (λ) maxima and band intensities.

Knowledge of the characteristics of light sources and detectors, and the effect of detector-source combinations on spectral response.

Knowledge of basic laws of light absorption for quantitative analyses.

Experimental

Ability to use the instrumentation and associated operating procedures.

Ability to optimize operating controls including wavelength, zero absorbance, slit width, amplifier gain and scanning speed.

Ability to choose appropriate solvents and to establish calibration curves for quantitative analyses.

Ability to study solvent and pH effects on spectra.

Additional analytical techniques used in forensic science

There are a number of additional analytical techniques suitable for forensic purposes, such as:

- Nuclear magnetic resonance (NMR)
- Isotope ratio-mass spectrometry (IRMS)
- Inductively coupled plasma-mass spectrometry (ICP-MS)

- Laser-induced breakdown spectroscopy (LIBS)
- X-ray diffraction (XRD)

A description of these techniques in term of equipment and related skill requirements is considered beyond the scope of this manual.

G. Databases

Databases are searchable collections of data or information, usually, but not necessarily, in an electronic/digital format. Digital databases are powerful tools used by forensic laboratories and allow the comparison of data and information from forensic casework with a large set of similarly classified data and information from previous cases and/or reference data, to assist with identifying materials in casework, to establish links with other cases and to assist with recognizing patterns.

The most well-known forensic national databases include those for fingerprints, DNA, and bullets and cartridge casings, but in-house databases also exist for samples of paint, glass, fibres, shoe and tyre marks, and chemical profiles of drugs. There are commercial, international databases, national databases, and laboratory-internal databases. In most countries national legislation exists which defines legal and technical requirements for these databases.

Related skills requirements (all databases)

Knowledge of various types of databases (e.g., local, state, national, missing persons, felon, population) and the appropriate use.

Knowledge of various search techniques and stringencies.

Knowledge of basic principles for comparison: one-to-one and one-to-multiple.

Knowledge of the risks associated with database searches.

Knowledge of legal requirements when establishing and using databases.

Awareness of protocol for obtaining confirmation sample. Any database hit, especially from a felon database, should only be considered probable cause to obtain a new reference sample from the indicated individual. Only after the profile from the documented independent sample is confirmed, should the evidence be considered reliable for use in court.

(a) Bullets and cartridge casings

e.g., IBIS (Integrated Ballistic Identification System)

Firearms evidence from shooting scenes and test-fires of guns found at a scene, especially bullet and cartridge casings ejected from autoloading weapons, is scanned and entered into the database. If the same weapon was used in a previous crime (or ultimately in a future one) the computer software will flag the evidence from the previous case so that the actual evidence item(s) can be retrieved and compared manually with the newly entered evidence item(s). If the examiner concludes that the items from the two different cases likely came from the same weapon, this is termed a “hit” and the cases may be linked or a suspect identified. Entering the data is time intensive, but since the introduction of this technology a number of useful “cold hits” have been generated.

(b) DNA profiles

e.g., CODIS (Combined DNA Index System)

Various databases of genetic profiles are used in forensic DNA analysis. For example, population databases are used to generate allele frequencies used in statistical calculations to determine the rarity of a profile. Many jurisdictions maintain a missing persons database so that remains and secondary reference samples can be searched against each other. Felon databases, consisting of samples collected from individuals convicted of certain categories of legally-defined crimes are maintained separately. Databases of unsolved case samples are also maintained. Suspect reference samples or evidence samples may be searched against either crime-related database to look for the potential contributor of a sample or a case-to-case link.

(c) Fingerprint identification

e.g., AFIS (Automated Fingerprint Identification System)

The computer systems used at present are able to scan fingerprint forms (i.e. reference inked or livescan prints) as well as fingerprints that have been found at a crime scene and automatically find and record the patterns, ridges, and ridge characteristics (minutiae) contained within. These data are then compared by the computer with information in the database to produce a shortlist of candidates in order of likeness (match probability). Fingerprint matching requires a large amount of computer power and sophisticated software algorithms. Fingerprint matching algorithms can vary greatly in terms of false positive and false negative errors. After a computer search has been completed, the crime scene fingerprint is compared manually by trained fingerprint specialists to identify if a match actually exists.

PART III: CONSIDERATIONS ON LABORATORY SET UP

The following is a brief summary of key considerations when setting up a forensic science facility. It provides some initial guidance but does not replace the careful planning, in each individual case, with the assistance of a dedicated laboratory architect or design/build team, and involvement, from the beginning, of the scientists who will occupy the facility to allow them to explain their special requirements for the laboratory.

The measure of a forensic laboratory's success is how well it meets the current and future needs of the occupants. There is not one universally-accepted plan for designing an effective forensic facility. Space, dimensions and overall design are determined by each laboratory's specific needs, including functional requirements of the envisaged forensic sciences disciplines that are to be accommodated and of the equipment to be procured. Based on successful results and the effectiveness demonstrated in previous laboratory designs, it has been shown that flexibility is also a key element in driving the configuration and design of a forensic science facility. Beginning with adequate office and laboratory space for the range of activities to be undertaken, the best forensic laboratories are designed in a way that allows for flexibility to adapt to changing law enforcement directions and technological developments.

To ensure maximization of laboratory functions and quality results, the physical design of a forensic science facility should be guided by the following principles, namely:

- Ensure the security and non-contamination of exhibits and the confidentiality of laboratory operations,
- Ensure the security, health and safety of the staff working in the laboratory
- Facilitate the flow of evidence from receipt in the laboratory to analysis and disposal/return to the customer.

The ISO/IEC Standard 17025 outlines general requirements for the establishment of laboratory facilities:

- The laboratory facilities, including energy sources, lighting and environmental conditions, must be appropriate for the tests being performed and environmental conditions must not invalidate the results or otherwise adversely affect the required quality of any measurement. Specific considerations must be given to environmental factors such as:

- Biological sterility (e.g., a DNA profiling laboratory must have a separate room for PCR amplification and a one-way path through the room; mitochondrial DNA (mtDNA) analysis needs a clean facility separate from other DNA activities)
- Dust
- Electromagnetic interferences (e.g. the use of shielding, proper cable layout, proper equipment grounding, proper rack grounding, and limiting the use of cell phones, radios and pagers in the lab is a key requirement for DME facilities)
- Radiation
- Temperature and humidity
- Stability of electrical supply
- Sound and vibration levels,

- Incompatible neighbouring activities must be adequately separated, e.g.:
  - Drying area for bloodstained items and DNA profiling laboratory,
  - Firearms examination area and GSR analysis
  - Vehicle examination area and fire debris analysis
- Measures must be in place to avoid cross-contamination, e.g.:
  - Clean room for examination of victim's clothing must be separate from another clean room that can be used to examine suspect's clothing.

Additional considerations include access control to analytical areas, the clear delineation between areas for administrative/clerical work and laboratory areas used for testing, and adequate environmental conditions, such as adequate lighting, plumbing, electrical wiring, ventilation, temperature and humidity control, and fire suppression systems (should generally preferably not be water-based). Where necessary, uninterrupted power supply (UPS) should be designed into the facility, as well as backup generator power be part of the design.

In addition to international standards for testing laboratories (i.e. ISO/IEC 17025), the laboratory will also need to comply with local legislation.

In addition to the design of the laboratory building, consideration must also be given to the site generally, i.e. the location (landscape) of the anticipated facility, which has implications for security, access to the site, proximity of secured and unsecured parking areas, waste disposal, etc.

Finally, when considering setting up a laboratory system and not an isolated laboratory, it is also important to define the role and responsibilities of subsidiary laboratories vis-à-vis the central laboratory. For example, subsidiary laboratories could operate with a limited analytical capacity, focussing on pre-assessment of each case and definition of the problem before sending samples to the central laboratory.

Further reading

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Annex 1. Common use of techniques in the various forensic science fields

Annex 1. Routinely used forensic techniques

Techniques \ Field		Illicit drugs and precursors			Shoemarks and tyremarks			Questioned documents		Firearms and toolmarks				Fires and explosions		Fibres, paints, glass and other microtraces			Digital and multimedia evidence			
Techniques \ Sub-field		Seized material	Biological sp	Fingerprints	Shoemarks	Tyremarks	Biological material (incl. DNA)	Documents	Handwriting	Gunshot residues	Ammunition components	Tool marks	Serial numbers	Fire debris	Explosives	Fibres/hairs	Paint	Glass	Computer forensics	Forensic audio	Video analysis	Crime scene investigations
Optical detection	Forensic light source (FLS)	X	X	X	X	X	X	X		X		X	X			X	X	X				X
	Multispectral imaging			X	X	X	X	X		X						X	X					
Electrostatic detection systems				X	X			X														X
Photography (general and specialized)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Preparation of inked exemplars				X	X	X																
Casting techniques for 3D marks				X	X	X						X	X			X						X
Microscopy techniques	Stereomicroscopy	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X				
	Brightfield microscopy	X					X	X							X	X	X	X				
	Polarized light microscopy (PLM)	X														X		X				
	Incident light comparison microscopy										X	X					X					

Microscopy techniques	Transmitted light comparison microscopy															X	X						
	Hot stage (melting point and GRIM)															X		X					
	Scanning electron microscopy(SEM)-EDX								X		X				X	X	X	X					
Colour tests (including luminescence and solubility tests)			X					X			X				X	X	X						X
Immuno-chromatographic tests			X	X				X															X
Microcrystal tests			X					X															
Density analysis																		X					
Serial number restoration techniques (etching and other methods, e.g., heat application, Magnaflux)														X									X
Techniques for fingerprint development and enhancement	Powdering				X	X																	X
	DFO-Ninhydrin-Indanedione				X																		
	Physical developer				X																		
	Cyanoacrylate fuming				X																		
	Detection of blood marks				X																		
	Detection on adhesive surface				X																		
	Other methods (e.g., VMD, MMD)				X																		
Chromatographic techniques	Thin layer chromatography (TLC)		X	X					X							X	X						
	Gas chromatography (GC)	FID	X	X											X	X							
		MS	X	X											X	X							
		Other detectors (e.g., NPD, ECD)	X	X											X	X							

Techniques		Field	Illicit drugs and precursors		Fingerprints	Shoemarks and tyremarks		Biological material (incl. DNA)	Questioned documents		Firearms and toolmarks				Fires and explosions		Fibres, paints, glass and other microtraces			Digital and multimedia evidence			Crime scene investigations
		Sub-field	Seized material	Biological sp		Shoemarks	Tyremarks		Documents	Handwriting	Gunshot residues	Ammunition components	Tool marks	Serial numbers	Fire debris	Explosives	Fibres/hairs	Paint	Glass	Computer forensics	Forensic audio	Video analysis	
Chromatographic techniques	Pyrolysis-GC (all detectors)								X								X	X					
	Headspace-GC (all detectors)		X												X								
	High performance liquid chromatography (HPLC)	UV	X	X												X							
		MS	X	X					X							X	X						
		Other detectors (e.g., DAD, RI, electrochemical)	X	X					X							X	X						
	Ion chromatography		X													X							
	Capillary electrophoresis (CE)		X	X												X							
Spectroscopic/metric techniques	Microspectrophotometry (MSP)								X								X	X					
	Ion mobility spectrometry (IMS)		X													X							X*
	UV-VIS spectrophotometry		X	X																			

Spectroscopic/ metric techniques	(Fourier transform) infrared spectroscopy	X	X					X							X	X	X					X*
	Raman spectroscopy	X	X					X							X	X	X					X*
	X-ray fluorescence (XRF)									X					X	X	X	X				
Techniques for DNA analysis (extraction and purification, polymerase chain reaction, CE separation)							X															
Techniques for digital and multi-media evidence analysis	Digital data recovery: write protection, imaging and hashing (verification)																		X	X	X	X
	Analog data recovery																			X	X	X
	Data extraction and analysis (incl. meta-, hidden and protected data)																		X	X	X	
	Data reporting and archiving																		X	X	X	

Legend:

X — technique suitable for analyzing the evidence type in routine casework

* — portable analytical instrument

Seized material — solid dosage forms

Biological sp(ecimens) — toxicology, drugs in biological specimens

Note: A technique is classified as "common use" in a specific field when this technique is used routinely in a modern, well-equipped laboratory environment. Techniques generally used for research purposes only are not included in this table. This table serves also as a basis for recommendations on the minimum requirements to commence casework in a selected forensic science field. Therefore this table is not exhaustive.

Annex 2. Description and classification of the techniques

Techniques		Cost (L, M, H)	Complexity of operation (L, M, H)	Interpretation (L, M, H)
Optical detection	Forensic light source (FLS)	L	L	L/M
	Multispectral imaging	M	L	L/M
Electrostatic detection systems		L	L	L
Photography (general)		L	L	N/a
Photography (specialized, e.g., advanced illumination methods)		L	M	M/H
Preparation of inked exemplars		L	L	N/a
Casting techniques for 3D marks		L	L	M/H
Microscopy techniques	Stereomicroscopy	L	L*	M/H
	Brightfield microscopy	M	M*	M/H
	Polarized light microscopy (PLM)	M	H*	H
	Incident light comparison microscopy	M	M*	H
	Transmitted light comparison microscopy	M	M*	H
	Hot stage (melting point and GRIM)	M	M	M/H
	Scanning electron microscopy-EDX	H	H	M/H
Colour tests (including luminescence and solubility tests)		L	L*	L/M
Immuno-chromatographic tests		L	L*	L
Microcrystal tests		L	M*	H
Density analysis		L	M*	M
Serial number restoration techniques (etching and other methods, e.g., heat application, Magnaflux)		L	L	L

Techniques \ Parameters			Cost (L, M, H)	Complexity of operation (L, M, H)	Interpretation (L, M, H)
Fingermarks development and enhancement techniques	Powdering		L	L	M/H
	DFO-Ninhydrin-Indanedione		L	L	M/H
	Physical developer		L	M	M/H
	Cyanoacrylate fuming		L/M	L	M/H
	Detection of blood marks		L	L	M/H
	Detection on adhesive surface		L	L	M/H
	Other methods (e.g., VMD, MMD)		M	M	M/H
Chromatographic techniques	Thin layer chromatography (TLC)		L	M	M/H
	GC (including headspace-GC)	FID	M	M	M/H
		MS	H	H	M/H
		Other detectors (e.g., NPD, ECD)	M	M	M/H
	Pyrolysis-GC-MS		H	H	M/H
	High performance liquid chromatography (HPLC)	UV	M	M	M/H
		MS	H	H	M/H
		Other detectors (e.g., DAD, RI, Electrochemical)	M	M	M/H
	Ion chromatography		M	M	M/H
	Capillary electrophoresis (CE)		M	H	M/H
Spectroscopic/metric techniques	Microspectrophotometry (MSP)		M	M	M/H
	Ion mobility spectrometry (IMS)		M	L	M/H
	UV-VIS spectrophotometry		M	L	M
	(Fourier transform) infrared spectroscopy		M	M	M/H
	Raman spectroscopy		M	M	M/H
	X-ray fluorescence (XRF)		H	M	M/H
Techniques for DNA analysis (extraction and purification, Polymerase chain reaction, CE separation)			H	H	M/H
Techniques for digital and multimedia evidence analysis					
Digital data recovery: write protection, imaging and hashing verification			M	M	M
Analog data recovery			M	M	M
Data extraction and analysis (incl. meta-, hidden and protected data)			M	H	H
Data reporting and archiving			M	M	N/a

Legend:

L Low

M Medium

H High

N/a Not applicable

* indicates that the analysis and the interpretation is done at the same time (i.e., person carrying out the analysis will be the same person doing the interpretation)

See report for details of what has been considered under "cost", "complexity of operation", and "interpretation".

Note: In column 3, average values are given for level of interpretation required; however, this can be extremely variable depending on the circumstances/evidence type.

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There is, in addition, a need for information on current trends in research and analysis. This may be obtained through subscriptions to specialized periodicals. Another way of ensuring awareness of the latest trends is to foster liaison and networking between national forensic laboratories in a geographical region as well as on a world-wide basis. UNODC also offers, on a regular basis, compilations of articles from the scientific literature.

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