UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF CRIMINAL ENFORCEMENT, FORENSICS, AND TRAINING

# ENVIRONMENTAL CRIME
## Technical Investigation--Evidentiary/Forensic Analysis


The following NEIC employees contributed to this paper.

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**Prepared for:**

13th International Forensic Science Symposium


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CONTENTS

## LIST OF ACRONYMS

AA – Atomic Absorption
A2LA – American Association for Laboratory Accreditation
AAAS – American Association for the Advancement of Science
ACS – American Chemical Society
AES – Atomic Emission Spectroscopy
AMTIC – Ambient Monitoring Technology Information Center
APHA – American Public Health Association
ASCLD/LAB – American Society of Crime Laboratory Directors/Laboratory Accreditation Board
ASE – Accelerated Solvent Extraction
ASTM – American Society for Testing and Materials
AWWA – American Water Works Association
CA – Chemical Abstracts
CAA – Clean Air Act
CAS – Chemical Abstracts Service
CASE – Court Appointed Scientific Experts
CE – Capillary Electrophoresis
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS – Comprehensive Environmental Response, Compensation, and Liability Information System
CFR – Code of Federal Regulations
CID – Criminal Investigation Division
CLU-IN – Hazardous Waste Clean-Up Information (Internet site)
CWA – Clean Water Act
DSMS – Direct Sampling Mass Spectrometry
EMC – Emissions Measurement Center
ETV – Environmental Technology Verification Program
FATE – Field Analytic Technologies Encyclopedia
FFDCA – Federal Food, Drug, and Cosmetic Act
FIFRA – Federal Insecticide, Fungicide and Rodenticide Act
FPXRF – Field-Portable X-Ray Fluorescence
FQPA – Food Quality Protection Act
GC – Gas Chromatography
GC-MS – Gas Chromatography with Mass Spectrometry
GC-AED – Gas Chromatography with Atomic Emission Detection
GC-FTIR – Gas Chromatography with Fourier Transform Infrared Spectrometry
GIS – Geographic Information Systems
GPO – Government Printing Office
HPLC – High Performance Liquid Chromatography
IC – Ion Chromatography
ICP – Inductively Coupled Plasma
ICP-AES – Inductively Coupled Plasma with Atomic Emission Spectrometry

ICP-MS – Inductively Coupled Plasma with Mass Spectrometry
ICP-OES – Inductively Coupled Plasma with Optical Emission Spectrometry
IMS – Ion Mobility Spectrometry
IR – Infrared
LC-MS – Liquid Chromatography with Mass Spectrometry
MAE – Microwave Assisted Extraction
MS – Mass Spectrometry
NEIC – National Enforcement Investigations Center
NELAC – National Environmental Laboratory Accrediting Conference
NELAP – National Environmental Laboratory Accreditation Program
NFSTC – National Forensic Science Technology Center
NTIS – National Technical Information Service
NVLAP – National Voluntary Laboratory Accreditation Program
OCEFT – Office of Criminal Enforcement, Forensics and Training
OIG – Office of Inspector General
PFE – Pressurized Fluid Extraction
PLE – Pressurized Liquid Extraction
PLM – Polarized Light Microscopy
PPE – Personal Protective Equipment
QA – Quality Assurance
QC – Quality Control
RCRA – Resource Conservation and Recovery Act
RCRAInfo – Resource Conservation and Recovery Act Information System
SEC – Securities and Exchange Commission
SFE – Supercritical Fluid Extraction
SPE – Solid Phase Extraction
SPME – Solid Phase Microextraction
SW-846 – Test Methods for Solid Waste
TIO – Technology Innovation Office
TSCA – Toxic Substances Control Act
TTN – Technology Transfer Network
UMEA – Ultramicroelectrode Arrays
UNEP – United Nations Environment Programme
US – United States
USEPA – United States Environmental Protection Agency
UV – Ultraviolet
VOC – Volatile Organic Compound
XRF – X-Ray Fluorescence
XRS – X-Ray Spectroscopy

## INTRODUCTION

This report is a compilation of information and advances in scientific and technical methods as applied to environmental crime investigations. Included are sections on information gathering and planning prior to a forensic investigation, evidence gathering techniques and field methods, tools of the investigation (computer forensics, link analysis), laboratory methods and instrumentation, and examples of laboratory fraud encountered. The planning section is a guide for the topics presented in this paper and it outlines the thought process and flow of events in an environmental crime investigation.

Literature of particular interest or with foundational reviews regarding methods, instrumentation, or techniques have been included in the search for current methods and upcoming trends in this field. This arena of environmental crime is expansive and lists of additional resources (both print and electronic) have been provided in the appendix to aid the researcher who may require more information than the text of this paper provides. A list of acronyms used in this paper is included after the table of contents.

Within this paper some commercial products, firms, or trade names may be mentioned. The mention of such does not constitute an endorsement or recommendation of those specific products or companies by the United States Environmental Protection Agency (USEPA) or the USEPA National Enforcement Investigations Center (NEIC). Names of this type mentioned within the text are intended solely as an aid to the reader within the context of the topic. Many of the Internet sites given in this paper do not have any connection with USEPA and, therefore, are not under any editorial control by USEPA.

The United States federal laws, and the methods approved for use by the USEPA, provide the frame of reference for the points of view expressed in this paper. This perspective and many of the issues and legal considerations that are dealt with in the United States are presented to aid in understanding the concerns relevant to environmental enforcement in the US. Each nation has their own sovereignty with regard to environmental regulations and environmental crimes. The methods used and types of environmental pollution control approaches will differ from nation to nation and the viewpoints presented in this paper are not intended as a standard for all to follow.

The purpose of this paper is to share general information on the enforcement of environmental laws within the law enforcement community. It does not set any absolute requirements under any legal system nor does it create any rights, substantive or procedural, enforceable at law by any party to litigation. In addition to literature references, this paper includes much practical information developed by NEIC over several years of helping develop environmental criminal cases. This information is presented for its value to potential users of this paper. This information may or may not apply in any specific case. It should always be understood that there are many ways of approaching any environmental problem.

Common environmental crimes in the US include illegal disposal of hazardous waste, unpermitted discharges to sewer systems or surface water, discharge of oil by vessels to waters within US jurisdiction, the misapplication of pesticides, the illegal importation of ozone-depleting substances, data falsification, and laboratory fraud. Federal, state, and sometimes local statutes and regulations are in place to protect the water, air, land, and human health. From a Federal perspective, these include the Resource Conservation and Recovery Act (RCRA) for hazardous wastes, the Toxic

Substances Control Act (TSCA) for toxic substances, the Clean Air Act (CAA), the Clean Water Act (CWA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for abandoned waste sites, and the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) for pesticides. Each of these laws contains some standard methods for sampling and analyses to prove environmental crimes. [1,2] The Code of Federal Regulations (CFR) contains the specific requirements of the laws. [3,4] Within the USEPA, the Criminal Investigation Division (CID) of the Office of Criminal Enforcement, Forensics and Training (OCEFT) is tasked with the responsibility to investigate criminal offenses. [5]

Criminal offenses are more serious in nature than civil violations in the United States. To successfully prosecute an environmental criminal case, the government has to prove, beyond a reasonable doubt, that a corporation or person knowingly violated an environmental statute containing criminal sanctions. The same analytical objectives of providing good quality data and accurate measurements prevail in both civil and criminal cases; the only distinction between the two are legal.

## ENVIRONMENTAL CRIME SCENE EXAMINATION

### INTRODUCTION

"In the fields of observation chance favors only the prepared mind." [6]

- Louis Pasteur
Inaugural lecture, University of Lille,
December 7, 1854

Proving environmental cases can be difficult due to both technical and legal complexities; penalties vary depending upon the statute and technical issues require ever-increasing knowledge from the investigative team.

The criminal prosecution of environmental crimes in the US is in its infancy. While a few scattered efforts at environmental crime prosecution occurred during the 1970s, the US federal government prosecution of environmental crimes substantially increased in the 1980s. Around that time, environmental laws were being developed or were being enhanced from misdemeanor criminal penalties (any crime punishable by less than 1 year in jail) to felony (any crime punishable by more than 1 year in jail) provisions. The following are some challenges that must be met by the investigative team.

- Scientific and technological advances throughout the years have improved our understanding of complex issues involved in environmental crimes, such as chemical fate and transport. As a result, the effective use of the increasingly sophisticated information sources and evidence collection tools that are becoming available for intelligence gathering, surveillance, field screening and measurements, laboratory analysis, and modeling pollutant behavior in the environment is required.
- All the scientific tools and technological capabilities, along with the resources required to investigate an environmental case, need to be singularly focused to prove the allegations. Scientific and technical conclusions then need to be presented cogently so a jury can clearly understand that the defendant committed the crime.
- One familiar tactic used by defense attorneys is to confuse the jury with the complexity of the evidence. The more complex the science, the more difficult it is to explain to a jury. Although the evidence exists to prove the case, the defense has a responsibility in the US legal system to represent the client to the best of his/her ability. Defense counsel will often try to convince a jury that a crime was not committed willfully and knowingly because the defendant could not have comprehended what was expected.
- Another challenge can be convincing a prosecuting attorney of the importance of an environmental case when he or she has competing, high visibility cases involving murder, drugs, and other high profile crimes. "Environmental crime is real crime; improperly disposed pollutants poison community water supplies, contaminate fisheries, and injure human beings." [7]

To overcome these challenges, environmental cases must be legally and technically sound, and presented in a straightforward manner. Documenting and illustrating to the court the impact to human health and the environment is also important.

## PLANNING

Understanding what crime has been allegedly committed and who was involved is the first step. Organizing and planning a case using a team approach is critical, as is communication between team members. Often, multiple government agencies are involved with a case, which makes communication more of a challenge. Each team member must have a clear objective and take care to do a thorough job on his/her own piece of the investigation, but interaction with other members of the team is also needed to ensure continuity.

In the United States, a lead criminal investigator, commonly referred to as the "case agent," is usually in charge of the overall process of investigating an environmental crime. The case agent develops an understanding of allegations of criminal activities, and consults with various witnesses, peers, and experts to decide what evidence is needed to ultimately prove the case. A recent book by Drielak titled Environmental Crime: Evidence Gathering and Investigative Techniques describes on-site environmental crime investigations. The author covers the issues related to search warrants and techniques used to gather evidence. Many photos from real environmental crime scenes are included to illustrate the topics in the book. [8]

A typical case requires knowledge of many fields within science, technology, and law. The case agent may need a team with a mix of knowledge of engineering (chemical processes and technology, field techniques and instrumentation), chemistry (laboratory sample analysis, chemical reactions and processes) and law (environmental regulations). The appropriate team members and experts will depend on the type of case being pursued and the personnel resources available. The case may require assistance from individuals skilled in gathering background information, seizing computer data, or detecting laboratory fraud.

Experts, either internal or outside the enforcement organization, can be especially valuable when they understand and communicate the interplay between legal requirements, science and technology, and the crime allegedly committed. Experts should not only understand their own field, but should be able to explain their opinions clearly and openly to other team members, to the prosecuting attorney, and ultimately to the jury without bias or condescension.

During the investigative process, a decision is often required regarding the need to conduct one or more searches for evidence. In the US, evidence must be gathered in accordance with the Federal Rules of Criminal Procedure and other federal guidelines designed to protect the individual's constitutional rights. [9] Methods used to obtain evidence of a crime include the use of consent searches, search warrants, and grand jury subpoenas. Sampling that is done on a consensual basis is not recommended because consent can be revoked at any time. If a search warrant is necessary, the agent will need to articulate what probable cause exists that a crime has been committed and that the location requested for the search contains the evidence of the crime. The case agent may articulate probable cause through evidence gathered from a variety of sources including witness interviews, surveillance of suspects, use of informants, as well as sampling of suspected discharges from the targeted facility. The agent will need to anticipate who will be physically present, what samples will be collected, and what documents will be seized. Samples may be collected during criminal investigations to establish probable cause for a search warrant, provide evidence, or both.

Execution of search warrants can require extensive planning. Ongoing communication regarding goals, problems, and objectives, including face-to-face meetings enable the team to work collaboratively to plan the field objectives, and to make the best use of the limited time available on-site. Generally, warrants are required to be executed during the hours of 6 a.m. to 10 p.m., unless a special situation is involved, such as a chemical release that can only be sampled as the release is occurring.

If releases of regulated pollutants to air, water or land are suspected, and sample evidence is to be collected, a field team leader should be identified. The field team leader is responsible to ensure that conditions are safe for workers, that the proper evidentiary samples are collected, and that field activities and observations of on-site conditions are documented. Any field measurements must be performed according to accepted procedures, and, as always, must be documented.

Safety of the field team should always take precedence over evidence collection. Safety considerations while conducting a search can include hostile individuals, chemical exposure and/or chemical incompatibility hazards, working under unpleasant and/or toxic conditions, collecting samples or searching in high places (for example, on top of tanks), and working around heavy equipment or industrial machinery, or working in confined spaces.

Manufacturing processes often need to be evaluated in detail to understand how chemicals are produced and what wastes are generated. Industrial waste treatment and management systems often need to be evaluated in detail. For example, waste tanks and associated piping may need to be identified to see if there is a connection to a sewer where an alleged release occurred.

The field team leader should maintain contact with the laboratory personnel to discuss sampling activities, to ensure that appropriate analytical techniques are available for use, and to ensure that resources are available to complete the analyses within applicable holding times (established time limitations for sample analysis). Multiple laboratories may be involved, for example when both hazardous waste and radionuclides are contaminants of concern. Laboratory personnel should be involved as early as possible in the planning process. The analytical chemist(s) should be familiar with the types of samples being collected, the purpose of each sample in proving the case, and the appropriate analytical methods to be used to prove the allegations.

Documentation of the analysis may include laboratory notebooks, bench sheets, instrument printouts, instrument calibration, and confirmatory analysis by alternate methods. Expert opinions may be required regarding chemical compounds and the fate and transport of contaminants.

Evidence preservation is a critical step in prosecuting any case, and environmental cases are no exception. As part of the Federal Rules of Evidence, it is the burden of the government to prove that any evidence presented in court is authentic. Challenges may be made to every step of the investigative process in an attempt to show that evidence was improperly handled. This includes sampling, transportation, physical and chemical analysis and sample storage. If care is not taken to properly preserve evidence and maintain chain of custody in every step of the investigative process, the evidence may be inadmissible at trial.

Testimony typically occurs long after the technical work is complete, and many details will need to be recalled. The investigative file should contain records of interviews, photographs, video recordings, sketches, field project plans, laboratory quality assurance project plans, correspondence, field notes, chain-of-custody records, calibration records, laboratory bench sheets, reports, and other pertinent records. The case agent should maintain contact with the team members involved in evidence collection. The team members should be kept informed about the progress of the case so they can provide input to conclusions about the evidence they collected and any limitations on its use. In advance of the trial, each person should be contacted about potential testimony so they can prepare.

Two regional offices within the USEPA have prepared manuals on environmental investigations. These are available through the regional Internet sites. Region 4 (offices located in Atlanta, Georgia) has prepared the "Environmental Investigations: Standard Operating Procedures and Quality Assurance Manual." It contains information about different types of investigations, forms and recordkeeping, sampling design, quality assurance (QA), and procedures for various sampling media, and an extensive listing of field procedures. [10] Region 10 (offices located in Seattle, Washington) has prepared an online manual, "Conducting Environmental Compliance Inspections." There are four main sections to select from: Inspection, Safety, Legal Considerations, and Evidence. There is also a Photo Gallery section that includes pictures taken from site inspections. An alphabetized index of the topics from the manual is also provided for the reader. [11]

## GATHERING INFORMATION

Background information for an environmental crime investigation is available from an extensive and expanding wealth of sources and in many formats. In the information age, a forensic investigator can answer the basic questions of "Who?," "What?," "Where?," "How?," "When?," and even "Why?" through research in print and computerized sources.

"Using On-line Searches in Investigations," is a seminal article exploring the online research tools available for fact-finding and discusses the pros and cons of commercial database research versus Internet resources. [12] Other publications outlining research resources include The Investigator's Little Black Book which covers topics on experts, organizations, and publications from "Accident Reconstruction" to "Zip Code Information." [13] Sources of Information for Criminal Investigators, prepared by Anacapa Sciences to support their courses in investigation methods and criminal analysis, is a valuable compilation for information resources. [14] General sources like these point to specific sources for background information.

The following sources answer the questions of "Who?," to find out about the corporation or individual(s) suspected of criminal activities, and "Where?," to locate possible crime scenes and to link together the properties owned by the suspect(s).

- **Dun and Bradstreet Services** provides business histories, operations, public filings and credit ratings with an international scope. The service also provides access to information on more than 58 million global companies. [15]
- **EDGAR**, the Electronic Data Gathering, Analysis, and Retrieval system, performs automated collection, validation, indexing, acceptance, and forwarding of submissions by companies and others who are required by law to file forms with the US Securities and Exchange Commission (SEC). [16-18]
- **Directory of Corporate Affiliations** is a business information source offering corporate linkage coverage, making it a trusted guide to corporate families in the US and worldwide. [19]
- **Autotrack** and **CDB Infotek**, database services available from ChoicePoint Company, are US nationwide providers of organized online public record data and other information services that are used to detect fraudulent activity, locate people and assets, and verify information and identities. [20]

- *info*USA is regarded as a comprehensive and accurate source of business and residential information covering nearly 12 million US businesses, 1.1 million Canadian businesses, 125 million US households, and 12 million Canadian households. The company provides information in a wide range of formats ranging from CD-ROM and Internet access to the more traditional printed materials. [21]

Additional information about the crime scene can be obtained using Geographic Information Systems (GIS). These systems are a powerful tool in assembling and evaluating multiple information sources with respect to a particular site. Maps can be prepared depicting many layers of data such as buildings, surface water bodies, soil types, utilities and sewers, and other pertinent features. The maps provide a graphical representation of site conditions, the surrounding environment, and potential receptors (such as a sensitive ecosystem or a school building). [22-25]

"How?," as in how a particular chemical product or by-product was produced, might be the next question for the investigator. Based on known facility and business descriptions, other resources can be tapped to learn about the processes, raw materials, and waste streams that may be on a site.

- **Kirk-Othmer Encyclopedia of Chemical Technology** is a library of information for the chemical industry. The latest version of this 27-volume encyclopedia is now complete and includes CAS registry numbers and in-depth information on regulations, patents, and licensing. Articles primarily focus on chemical substances or industrial processes. [26]
- **Ullmann's Encyclopedia of Industrial Chemistry** is another massive source of information on chemical industries. This encyclopedia has a 40-volume print set that covers the basics of theoretical principles and fundamentals of chemical engineering along with practical knowledge of unit operations and plant construction with specific company examples. A newer electronic edition is also available. [27]
- The USEPA's Office of Water has published a series titled "**Development Document for Final Effluent Limitations Guidelines and Standards**" for many industries. Included in this series are the Landfills Point Source Category, the Alkaline Coal Mining Subcategory, the Metal Products and the Machinery Point Source category among others. Diagrams and descriptions of industrial processes are provided in the series. [28-30] These documents are distributed through the National Technical Information Service (NTIS). Further details about NTIS are provided in the appendix.
- The USEPA's Office of Compliance has developed a series of profiles or **Sector Notebooks** containing information on selected major industries. Each notebook includes a comprehensive environmental profile, industrial process information, pollution prevention techniques, pollutant release data, regulatory requirements, contact names, compliance and enforcement history and bibliographic references. [31]

Before beginning the on-site investigation, the investigator should explore "What?" chemicals might be found at the site and the potential risks posed by those chemicals. Many resources can provide this information. Recent articles point to sources of toxicological information. [32-35] Some sources are available on the Internet at no cost.

- The **Global Information Network on Chemicals** (GINC), is a world-wide information network for the safe use of chemicals. From this homepage you can explore useful information sources provided by both international organizations and national institutions collaborating for safe control of chemicals. [36]

- The **MSDS search** Internet site is a good starting point for locating manufacturers' material safety data sheets (MSDS). MSDS provide detailed information about the hazards of a particular chemical and references to further information about that chemical. An added feature includes links to translation services that provide MSDS in many languages. [37]
- Also available on the Internet, but for a fee, is the **Chemical Abstracts Service** (CAS). CAS is the producer of the world's largest and most comprehensive databases of chemical information. The principal databases, Chemical Abstracts (CA) and REGISTRY, now include about 16 million document records and more than 30 million substance records, respectively. CAS also produces databases of chemical reactions, commercially available chemicals, listed regulated chemicals, and compounds claimed in patents. [38]

An overview of forensic techniques for answering the question of "When?" is presented in a recent article by Morrison. [39] The techniques for age-dating include corrosion models for underground storage tanks, commercial availability of a chemical, stable isotope analysis, degradation models, biomarkers, and contaminant transport models.

- The **Integrated Model Evaluation System** (IMES) is an interactive system for selecting fate models (air, surface water, groundwater and multimedia) most appropriate to the needs of an exposure assessor. It includes information on over 100 models that address items such as the input requirements, level of detail, required user expertise, applications, and validation. It is distributed on a CD-ROM that includes many of the fate models themselves and their manuals. [40-42]
- The **Environmental Fate Data Base** (EFDB) was developed under the sponsorship of the USEPA to allow rapid access to all available fate data on a given chemical and to provide a data source for constructing structure-activity correlations for degradability and transport of chemicals in the environment. The EFDB is a tremendous aid in identifying persistent chemical classes as well as the physical or chemical properties that may correlate to particular behavior in the environment. The EFDB is composed of several interrelated files–DATALOG, CHEMFATE, BIOLOG, and BIODEG. These databases share a CAS number file containing over 20,000 chemicals with preferred name and formula and a bibliographic file containing full references on over 35,000 cited articles. [43]

"Why?" is a more difficult question to research, but the motivation behind an environmental crime may be indicated in financial information sources and by reviewing the suspect's compliance history.

- The **Financial Crimes Enforcement Network** (FinCEN) of the US Department of Treasury supports law enforcement investigative efforts and fosters interagency and global cooperation against domestic and international financial crimes. FinCEN is a network linked between law enforcement, financial, and regulatory communities. FinCEN strives to work with its domestic and international partners to maximize the information sharing network and find new ways to prevent and detect financial crime. [44]
- The USEPA created the **Envirofacts Warehouse** to provide the public with direct access to the wealth of information contained in its databases. The Envirofacts Warehouse allows searching on a company or facility name to retrieve environmental information from across

USEPA databases (such as the Toxic Release Inventory, RCRAInfo, and CERCLIS). A USEPA-internal version of Envirofacts allows retrieval of compliance data as well. [45]

Although not a comprehensive listing, this overview of information sources for environmental crime enforcement would be incomplete without the following references to these important information systems.

- **LEXIS/NEXIS** and **Westlaw** are two commercial, computerized legal research systems which provide access to case decisions and other public records. These records show the legal histories of companies and individuals as well as the statutory and regulatory issues. Most easily accessed online, these systems also produce traditional print products. NEXIS provides many full-text newspapers, journals, financial reports and news wires from around the world. [46,47]
- **DIALOG** is potent information retrieval service providing access to more than 600 databases spanning business, science, and technology, many providing full-text online. [48]
- **UNEP-Infoterra** is an international environmental referral and research network made up of 177 countries coordinated by the United Nations Environment Programme (UNEP) in Nairobi, Kenya. The US National Focal Point for UNEP-Infoterra is located at the USEPA Headquarters Library and is managed by the Office of Environmental Information. The services offered by UNEP-Infoterra/USA to requests for environmental information from the international community include document delivery, database searching, bibliographic products, purchasing information, and referrals to experts. [49]
- **INTERPOL**, the International Criminal Police Organization, has an Environmental Crimes Committee to combat environmental crime. Member nations fill out "Eco Messages" on international environmental crimes for INTERPOL. These messages are compiled in a database, analyzed, and circulated to other member nations for the purpose of coordinating international law enforcement in the fight against environmental crime. [50]

## GATHERING EVIDENCE

Evidence gathered at a crime site typically involves interviews, visual observations, measurements, sampling, and seizure of paper documents and records and electronic data. The following sections describe techniques and sources of information with respect to field measurements, sampling, and retrieving electronic data. Interviewing techniques will not be covered in detail.

Field work is always a challenge, and regardless of the amount of advance preparation, the unexpected can happen. The team should be able to anticipate and plan for many potential issues and problems commonly encountered during the execution of a search warrant. Environmental crime search warrants often entail unique challenges such as chemical exposure risks and safety issues. Heavy equipment may be needed, unknown chemicals may be present; large quantities of waste may be involved; and the terrain, temperature, or weather may make sampling more difficult. To minimize the impact of the unexpected, a well thought out and detailed plan should be developed and discussed by the team. The plan should be detailed in writing to the extent possible, based on available information, and should evolve as new information becomes available.

## Field Techniques and Equipment

From a few key sites on the Internet, a wealth of knowledge regarding techniques, tools, instrumentation, and sampling in the field can be obtained. The following Internet sites have seemingly endless links to this type of information.

- USEPA's **Technology Innovation Office** homepage contains links to publications that can be viewed, downloaded, or ordered. There is a section for site characterization that includes information on technology and tools and educational materials. Links to international updates (conferences, newsletters, Internet sites) and to another informative site maintained by the TIO abbreviated CLU-IN. [51]
- The **Hazardous Waste Clean-Up Information** site, also known as **CLU-IN**, has documents, reports, videos, and software on various topics related to methods, techniques, and developing technologies all ready to be downloaded by the user. Options available on the site include the opportunity to sign up for email newsletters that highlight new publications and events of interest to site assessment and site remediation professionals. Users can also register for live Internet events–online seminars with a web-based slide presentation and options for accessing the audio portion of the presentation. [52] One of the best sections of this website is the Field Analytic Technologies Encyclopedia (FATE). The training modules in FATE cover geophysical, organic chemical, and inorganic chemical characterization techniques and data interpretation and include information about work plans and data quality objectives. Most of these modules are presented on-screen as a slide-show presentation with notes for each slide. Supplemental information and sources for information are generously spread throughout the training program. [53] The analytics listing in the technologies section has links to further information about the technologies listed such as the description, theory of operation, target analytes, performance specifications, limitations, cost data, and links to vendors. [54] A free seminar on systematic planning and innovative field measurement technologies is available on the CLU-IN site. Users can download the seminar (including the speaker's notes) in one of three different formats. [55]
- **USEPA REACH IT** (abbreviation for **REmediation And CHaracterization Innovative Technologies**) has an online searchable database of innovative and conventional technologies for characterizing or treating hazardous waste sites. The search guides the user through questions on the contaminant group of interest, the type of media involved, and the technological scale desired to reach its results. Details provided on the technology includes a description, verification information, uses by media type, technical support needed, and a cost analysis. A vendor database allows the user to search for providers of specific technologies and gives the vendor's Internet site if available. [56]
- **ETV**, the USEPA's **Environmental Technology Verification Program**, was established to verify the performance of new environmental technologies to help accelerate their use. On this site, verified technologies are listed by media and by specific pilot programs and each technology item includes a verification statement and report. Links to the Internet sites of project partners, USEPA sites, associations and international sites are also included. [57]

An easy-to-use and informative guide on field sampling and analysis is located on the Federal Remediation Technologies Roundtable Internet site. [58] Two field sampling and analysis guides exist on the site. One guide covers field sampling and collection techniques with information on tools and extraction methods cross-referenced with analytes, type of sample media, and technology details. The tools and extraction methods have links to more specific details on the item such as a basic description, limitations, and any applicable ASTM standards or USEPA methods. [59] The other guide is a matrix that cross-references sample analysis tools (techniques or instrumentation) to analytes, sample media, susceptibility to interference, detection limits and more. Just like the other matrix, the analysis tools listed here have links to further information. The additional details that can be obtained include description of the technique or instrument, the applicable uses, the turnaround time per sample, the cost per analysis, limitations, and any applicable ASTM standards or USEPA methods. [60]

Drum, et al., recently published a textbook-style handbook to detail analytical tests in the field. The book provides an overview of environmental testing in the first section and divides tests in the rest of the book by the type of media. Directions are specific to certain manufacturer test products. Step-by-step instructions, diagrams, and question-and-answer sections are included for each analytes. [61]

Field Analytical Chemistry and Technology, a periodical published by John Wiley & Sons, regularly features papers in categories of "Technology Reviews," "Application Reviews," and "Outfield Reports." [62] These reviews and reports are specifically requested by the journal editors when readers ask for articles on a particular subject. The "Outfield Reports" describe multi disciplinary teams involved in significant field analytical projects. Some issues are dedicated to a single topic such as the 1999 issue on Open-Path Fourier Transform Infrared Spectroscopy (Volume 3, Issue 2).

Recent papers that discuss developments or trends in field work were searched in the literature. The papers have been categorized into the topics below.

Field Analytical Chemistry

- Substantial review paper from 1997; topics covered include portable instrumentation, sensors, mass spectrometry, gas chromatography, field methods and applications, and immunochemical techniques [63]
- Outfield report on work plans and field analysis for hazardous waste site investigations; cost comparisons of traditional and dynamic field investigations; site application examples [64]
- Technology review of trends and advances in field-portable analytical instrumentation; outlines operational characteristics that make a "fieldable analytical instrument;" list of past, present, and future field analytical technologies [65]

Aerosol Measurement

- Review of literature on laser-induced plasma spectroscopy with emphasis on analysis in gaseous and aerosol phases; technique presented as potential next-generation field portable instrument for characterizing metal species [66]

Volatile Organic Compounds (VOCs)

- Review of specific recent developments for the analysis of VOCs in ambient air and natural waters; includes applications in the field [67]

Petroleum Hydrocarbons in Soils

- Technology review on direct-push fluorescence-based sensors for determining subsurface chemical contaminants; different systems and configurations presented [68]

Atomic Spectroscopy

- Review with emphasis on field-portable atomic spectrometry; includes a table of selected applications of laser-induced breakdown spectroscopy (LIBS) with elements, matrices, and limits of detection [69]

Biosensors

- Technology review of biosensors and the potential for use in screening and monitoring; list of analytes and biosensors provided [70]

Field Portable X-Ray Fluorescence (FPXRF) Spectrometry

- Technology review of FPXRF; evolution and characteristic features of the field-portable XRF analyzer [71]
- FPXRF analysis of environmental sample; tables with list of available instrumentation and vendors and a comparison of calibration methods are included [72]
- Application of FPXRF from soil and sediment metals analysis to filters used in air monitoring [73]

Gas Chromatography-Mass Spectrometry (GC-MS)

- Technology review of advances in field-portable GC-MS; discussion and pictures of vehicle-portable and man-portable systems [74]
- Outfield report on fast on-site analysis of hazardous emissions from fires and chemical accidents; details on equipment, sampling and sample preparation, and applications; many figures of procedures and techniques are included [75]
- Mini-review on fast field screening of contaminated areas; overview of analytical methods for mobile GC-MS systems [76]
- Outfield report overviewing GC-MS uses including sections on environmental analyses by type of sample media [77]
- Outfield report on a modular laboratory designed for travel; list and diagram of system components [78]

Infrared (IR) analysis

- Portable IR analyzer for low-level hydrocarbon vapors; near real-time distribution data included [79]

Ion Chromatography (IC)

- Schematic layout and detailed discussion on a field-portable capillary ion chromatograph [80]

Ion Mobility Spectrometry (IMS)

- Technology review on capabilities and limitations of IMS for field screening uses; includes details on different spectrometers, detection limits for some pollutants and future developments [81]

Mass Spectrometry (MS)

- Technology review of direct sampling mass spectrometry (DSMS) in analysis of environmental samples; discussion of instrumentation, portability, analytical methods, and environmental applications [82]

Ultramicroelectrode Arrays (UMEAs)

- Review on UMEAs with emphasis on determination of heavy metals in environmental samples; table of analytes and media provided [83]

When assisting in the execution of a search warrant, the field team needs to ensure that the evidence collected is authorized by that warrant. [84] Each person involved in the case can ultimately be called as a witness later. Therefore, each person should keep this eventual testimony in mind when performing their work. When established procedures are used to collect evidence, it is often easier to defend their scientific reliability and legal acceptability. If field conditions necessitate deviation from standard procedures, the reasons should be documented. Testimony typically occurs long after field work is complete, and many details will need to be recalled. Good documentation will make that task easier.

Once the field work begins, the crime scene should be secured, checked carefully for safety hazards, and documented using photography, video recordings, and extensive written notes. Prior evaluation of manufacturing processes and waste management procedures will provide information needed in finalizing the sampling decisions on-site. Often before sampling, a chemical "hot zone" is established and delineated. Everyone permitted into the area should have current safety training and the appropriate level of personal protective equipment (for example, chemical resistant suits, hard hats, gloves, etc.).

When possible, field measurements should be performed according to accepted procedures, and be well documented. Field monitoring and measurement equipment should be maintained and calibrated, and periodically checked to ensure they are working properly. All these steps are recorded (even those steps that occurred prior to entering the site). In the US, chain of custody is usually required to be maintained for any item that will be introduced in legal proceedings. Interviews should be recorded along with field activities such as sampling and environmental measurements. Marking, labeling, preservation (if appropriate) of environmental and waste samples, shipping, and observance of any applicable quarantines (for example certain soils or vegetation shipped across geographical boundaries) should all be a part of the permanent record of the site visit.

## Sampling

Sampling evidence can be divided into categories in many ways. One common way is by the contaminants released such as volatile compounds, toxic materials or "heavy metals." Another is by the media it is released into such as soil, air, surface water, or groundwater. Yet another way of categorizing waste is by the location at which it is taken such as inside a storage area, in a tank, or in a river, either upstream or downstream from a site. The approach to taking a sample depends upon which combination of categories it falls into; for example, a sample may be for volatile organic compound analysis from water taken downstream from a plant.

Sampling equipment can be as simple as a shovel and as sophisticated as a computer controlled robotic sampling device. Specialized sampling devices are available for many situations. The device selected should be appropriate to the material being sampled. Each sampling device should be inert to the material being sampled. Devices and equipment that are used more than once are often cleaned in advance and decontaminated between uses. Disposable sampling devices are sometimes the best choice. Sample containers used should be from a known source, inert to the material being collected, and free of any interferences to later sample analysis. A sufficient number of sizes and types of containers should be available in the field to collect an adequate sample volume to perform the required analysis and quality control measures. How samples will be packed, secured (chain of custody) as evidence, and transported to the laboratory for analysis should be considered prior to sending field personnel out to a site.

Sample records can include the source of any sample containers used, including such information as the company name, the lot number, the types of containers (including the size, color, and construction materials), and any tamper-proof seals used. It is often standard procedure to wear gloves while collecting samples and to change the gloves between each sample to avoid cross contamination.

Details regarding types of sample containers, preservation techniques, and holding times suggested by the USEPA can be found with the analytical test methods. Chapters 2, 3, and 4 within the Test Methods for Evaluating Solid Waste (otherwise known as SW-846) each contain useful tables for these procedures. [85]

Environment Canada has two extensive guides for field personnel when site investigation or sampling is necessary. The Inspector's Safety Guide provides details on protective equipment, hazardous substances, and potential hazards when inspecting industrial sites. [86] The industrial hazards section includes chemical hazards, safety precautions, emergency response actions, and other extremely valuable information specifically targeted to each industry type listed. The Inspector's Field Sampling Manual offers a full guide for sampling from early planning stages (data quality objectives, equipment and sampling plan checklists, quality assurance and quality control) to on-site actions (sampling protocol for specific media and laboratory tests) to shipment of samples. [87]

The CLU-IN Internet site, mentioned in field techniques section, also includes a few documents on sampling in addition to field materials. [88] An American Chemical Society (ACS) book on environmental sampling contains chapters on sample design, quality assurance and quality control, and sampling for specific media. The methods mentioned primarily refer back to USEPA methods. [89]

Many USEPA publications and Internet sites provide guidance for planning environmental sampling work. Chapters 9 and 10 within SW-846 cover sampling plans and sampling methods. [85] A USEPA guidance document on "Choosing a Sampling Design for Environmental Data Collection" has been prepared and is available to the public, but it is still undergoing peer review. [90]

A useful reference for soil sampling is the USEPA field pocket guide Description and Sampling of Contaminated Soils. [91] The American Society for Testing Materials (ASTM) has an extensive book of standards for environmental sampling with sampling information on a variety of media (soil, water, waste, air, and biological). [92] Standards include terminology, diagrams, material and apparatus lists, calculations, procedures, and numerous references. Also included is a standard on QA/QC for sampling activities. Many of these standards are referenced in USEPA's regulations.

Samples should be collected using procedures specified in the corresponding regulations and regulatory guidance, if possible. Quality assurance issues and the statistical significance behind the sampling plan can be crucial to decision-making in environmental forensics and having a statistician or another individual who understands both field and laboratory sampling issues on staff or available for consultation is highly recommended.

The purpose of each sample should be carefully thought out. Some US regulations require that samples be "representative" of the waste. What is meant by "representative" is sometimes defined in the regulation. These definitions vary between the different regulations. Understanding the role of each sample in proving the overall case is important. A sufficient number of samples should be collected from the appropriate areas to ensure that meaningful scientific statements can be made about the sampling target. Statistical calculations may be used to determine sample size and quantity needed.

Many statistical references and guides for environmental sampling exist. These cover the quality assurance and quality control (QA/QC) aspects of sampling, sampling theories, and examples of statistics used in environmental pollution studies. [93-98] A current USEPA guidance document on data quality assessment provides an overview of statistical tests. [99]

A simple and efficient "generic guide" to sampling survey designs has been provided by the Energy and Environmental Division of the American Society for Quality. In it, a logical order of steps in a sampling plan is presented along with explanations of key terms, issues, and a good summary of responsibilities for the scientific disciplines involved. It also includes information on quality control (QC) measures such as field blanks and equipment blanks and the purposes behind taking the blanks. [100]

The samples are often kept in a secure location under the control of the sampler, preferably in a locked, initialed container. Samples should be kept at temperatures appropriate for the type of samples taken and for the analytical techniques that will be used for testing. Wastes generated during the sampling should be properly disposed according to applicable regulations. Decontamination procedures are often followed for sampling equipment that is to be reused and to avoid spreading contamination outside the hot zone. Split samples are often collected to enable the defense to conduct an independent laboratory analysis.

Each sample container should be marked with a discrete identification number for tracking purposes. This can be done using numbered tags or bar codes. The lid of the container, if any, should be marked with the sample location as well as the container itself. Preservative should be added to the samples, if appropriate (many waste samples do not require preservation).

Samples should be shipped as soon as possible, within any applicable analytical holding times. [101] The samples are required to be packaged for shipment according to applicable regulations, in a manner that protects the containers from breakage or leaking. Samples of waste and contaminated environmental samples should be stored and shipped in separate containers from background samples to avoid cross contamination. Incompatibility of chemicals in waste samples must also be considered to avoid chemical reactions.

Restrictions for shipment of dangerous goods have been set by the International Air Transport Association in their Dangerous Goods Regulations Manual. [102] Restrictions may differ between airlines and countries for some hazardous items. Additionally, the US Department of Transportation has Hazardous Materials Regulations (49 CFR 100-185) covering all modes of shipping hazardous materials (ground, sea, rail, air). [103]

As samples are collected, the laboratory should be contacted from the field. The number of samples collected should be discussed as well as when the samples are expected to arrive in the laboratory. A specific person or persons should be identified to receive the samples in order to maintain a planned chain of custody.

Chain-of-custody records usually include a standard form documenting the delivery and the receipt of each sample collected. Personnel handling the samples are recorded from the initial contact at the crime scene through each sample transfer until the samples are received in the laboratory. [104] Under chain-of-custody procedures, samples are to be under the control of the investigation team at all times. The locations of each sample from the time of collection through the time of analysis in the laboratory are documented. This includes times when the containers are stored prior to shipment and after they are received by the sample custodian in the laboratory.

**Electronic Evidence**

The last 20 years has seen the proliferation of computers in work and personal environments and it comes as no surprise that computer forensics plays a part in environmental crime investigations. As discussed by Devaney, Lee, and Topper, the new high-tech area of computer forensics is being deployed by the USEPA Criminal Investigation Division in the investigation of environmental crimes. [105]

The environmental protection framework established in the United States leaves open a few areas of concern for computer forensic experts. Large portions of all compliance monitoring is done on a self-monitoring basis. A vast amount of this data is being generated by and stored on computers in either a laboratory environment or by computerized environmental monitoring equipment. Continuous emissions monitoring (CEM) systems are an example of the latter. These computerized devices are installed in power plants to take direct measurements of gases or particulate matter. After the computer converts these measurements to the units of the emissions standard, the information can be automatically sent to the responsible regulatory agency. A similar computerized database and reporting system is encountered in leak detection and repair (LDAR) investigations at refineries. These systems monitor fugitive emissions from the various valves, flanges, and pumps at the plant. While LDAR is primarily evaluated during civil environmental investigations, the computer forensic analyst's job is the same in both examples–to obtain the database or data that is generated during monitoring and analyze and compare the results to the reports submitted to the regulatory agency.

A developing area of environmental crime investigations involves laboratory fraud. Laboratory fraud is the deliberate misrepresentation of analytical results. This misrepresented data is often submitted to government agencies for regulatory determinations. In any laboratory setting, there can be a considerable variety of computers and computerized systems connected to laboratory instrumentation. These systems are capable of producing data ranging from raw data directly from the instrument to reduced data in the form of a report for a specific analysis. For this type of investigation, specialized knowledge of the operating systems and programs can be an invaluable aid in determining if fraud occurred.

The means of acquiring, securing, and analyzing computer evidence can vary. A traditional approach is to train investigators in computer forensic techniques. But due to the constantly changing technology in the computing industry, it is almost impossible for an investigator, who has many responsibilities in investigations, to keep up with the ever-changing technology. Another approach to this problem is to have a team of computer specialists work as fact-gatherers (seizing evidence) for the criminal investigator. Eoghan Casey highlights this cooperative approach between law enforcement, attorneys, and computer professionals in a recent book. [106]

Guidance for handling electronic evidence has been published by the US Department of Justice. [107] Two useful handbooks, one by Stephenson and an older one by Wilding, present the skills needed to assist in an investigation using the basic computer forensic concepts of preserving, collecting, and searching for evidence.[108,109] A book by Sammes and Jenkinson emphasizes four principles of handling computer evidence that can be used as a helpful guide in investigations.[110]

Additional problems areas, such as reverse engineering and internal data security issues, need to be addressed by computer forensic analysts prior to pursuing an environmental crime investigation.[105] Reverse engineering involves understanding the code for a computer program and using that knowledge to determine if the computer system can perform properly for its designed function. This type of study can ascertain if the results being produced and reported are reliable and are actually the true results or if the code contains an error that may lead to false results.

Data security issues within a company can become a serious issue when investigators try to determine if a suspected chemical release was accidental, a deliberate release, the action of a disgruntled employee, or the result of a computer hacker tampering with an automated system. This scenario can also apply to automated reporting systems that transfer data directly to a regulatory authority. These issues may require working with industry to find out if computer systems are performing accurately and effectively and to discover if an environmental incident indicates a larger problem related to computer security issues.

## LABORATORY ANALYSIS OF ENVIRONMENTAL SAMPLES

### METHODS AND METHOD SELECTION

The programs within the USEPA have been distinguished by the types of sample matrix or media (air, water, waste). These media-specific offices have issued or adopted a variety of methods, method manuals, and analytical requirements. Some of the most frequently used include the Test Methods for Solid Waste (referred to as SW-846), Title 40 of the Code of Federal Regulations (often abbreviated as 40 CFR), and the American Water Works Association (AWWA) Standard Methods for the Examination of Water and Wastewater. These testing methods are designed specifically for certain media, but may be used by multiple USEPA programs.

Method validation has become an important focus for laboratories. The need for laboratories to use fully validated analytical methods is discussed by Wood. [111] The first step in reaching a "full validation procedure" is identifying the analytical problem, any requirements of the customer, what is feasible for the laboratory (analytically and economically possible), and any other specific requirements. A few questions that could be addressed by a validation plan are listed below.

- When is the method going to be used? (Official controls and in-house process control methods may have to fulfill different criteria on precision and accuracy.)
- What type of answer is required–qualitative or quantitative?
- In what state is the analytes (bound or free)?

Wood provides details on requirements for method validation through collaborative trials and for methods validated "in-house." [111]

An early and basic guide to QA issues in the laboratory including analytical methods is provided by Dux. [112] Funk and co-workers provide a "4-phase model of analytical quality assurance" in their book. The phases take an analytical procedure from newly formed to routine usage to external examination. [113]

Another QA book focusing more on environmental monitoring and instrumental methods or techniques (for example, solid phase extraction, ICP-OES techniques, and capillary electrophoresis are included) has been compiled by Subramanian. [114] Details about the QA and QC needed for the analysis of airborne particles are presented by both Hopke and Biegalski in their chapters in a recent book. [115,116]

Berger, et al. compiled an impressive reference guide titled Environmental Laboratory Data Evaluation. This loose-leaf notebook divides into sections on scientifically valid data and overviews of many US environmental regulations. Within these overviews, methods are broken down into initial QC requirements and QC to be performed during the analysis. [117]

Eurachem, a network of organizations in Europe established to promote traceability and good quality practices, has some free, downloadable guides on quality in the laboratory. Many guides have been translated into several languages. Included in the titles are "The Fitness and Purpose of Analytical Methods: A Laboratory Guide to Method Validation and Related Topics," "Quality Assurance for Research and Development and Non-routine Analysis," and "Quantifying Uncertainty in Analytical Measurements." [118]

Analysts should be aware of potential problems with individual methods and review this information carefully before choosing or modifying analytical procedures. QC procedures should be used by the analysts to evaluate if the choice of the analytical procedures and any modifications are appropriate to satisfy the data quality needs of the intended application. [85]

### Hazardous and Solid Wastes

The Test Methods for Solid Waste, or SW-846, are used for environmental crimes involving the illegal disposal of hazardous waste. SW-846 is entirely accessible on the Internet. [85] The table of contents and chapter titles are provided for easy reference. Copies of SW-846 in print and on CD-ROM are also available. [119] The CD-ROM version has a helpful analytes to method cross-reference table.

Within SW-846, there is guidance for using the analytical methods. Key points that are developed within this guidance deal with the flexibility of the methods, the stringency of method-defined parameters, and comparing results obtained from different methods.

The flexibility of the methods allows the analyst to make their own choice of reagents, supplies, and equipment with the limitation that the method performance must be appropriate for the intended application. Data quality objectives for the analysis (or knowing just what is needed from the analysis) address the quality control (precision, recovery, and sensitivity, for example) needed for the analysis.

Quality control criteria is provided throughout the methods in SW-846. Many methods in a numerical series (for example, the 3000, 3500, or 7000 series) refer back to one key location for the QC information on that series. Chapter One also provides a quality control overview for both laboratory and field activities. Method-defined QC criteria maybe found in the specific methods. If inconsistencies are found between the general QC guidance and method-specific or technique-specific QC, the latter takes precedence. [85]

SW-846 also contains procedures for "method-defined parameters," where the analytical results are dependant on the process used to make the measurement. Examples of these are the toxicity characteristic leaching procedure (TCLP), the flash point, and pH. These procedures tie into regulations that specify certain limitations when classifying material as hazardous waste. Changes made to these methods may change the end result or cause a material to be incorrectly identified (either hazardous or nonhazardous).

Another cautionary note within SW-846 concerns comparing results from different procedures. Even though different methods may be designed to measure the same thing, they may still produce different results for a variety of reasons. Examples of these include differences in analytes recoveries between extraction techniques and differences between the digestion methods for metals analysis.

### Water and Wastewater

Violations of the Clean Water Act (CWA) often involve the illegal discharge of a pollutant to a body of water without a permit or in violation of an existing permit.

Methods for water and wastewater used by the USEPA come from various sources. Some have been prepared by the USEPA Office of Water but many others have been adopted for use from outside sources. The analytical methods prepared by USEPA encompass both organic and inorganic analyses and are available for purchase through NTIS (see appendix for more information).[120] Other USEPA analytical water methods are available in downloadable electronic format.[121] A collection of analytical methods, "Methods and Guidance for Analysis of Water," is available on CD-ROM. It contains most drinking water methods published by USEPA.[122]

The two primary sources from outside the USEPA are the American Water Works Association (AWWA) and the American Society for Testing and Materials (ASTM). The AWWA provides water methods in the Standard Methods for the Examination of Water and Wastewater. This reference book is available from the American Public Health Association (APHA).[123] ASTM water methods are taken from the Annual Book of ASTM Standards.[124] An online list of non-USEPA methods that may be used for analysis includes the source of each method, A list of sources with the links for the analytical methods in the water section has also been provided.[125,126]

**Air**

In the US, environmental crimes that involve violations of the Clean Air Act (CAA) are primarily related to the illegal removal and disposal of asbestos and the illegal importation of chlorofluorocarbons (CFCs). Asbestos is regulated under the Toxic Substances Control Act and the Clean Air Act.[127]

Crimes involving asbestos can have a significant impact on people who are part of the lower income groups in society. Many cases deal with asbestos removal jobs performed by indigent or immigrant workers who have not received training or personal protective equipment (PPE) to perform the abatement (removal) procedure. In one case, Spanish-speaking immigrants were "trained" with videos, but the videos were in the English language, not Spanish. Another case detailed abatement conditions so poor that deaf employees could not see each other well enough to communicate using sign language. Workers without proper training and PPE are exposed to asbestos fibers which can lead to lung cancer, a lung disease called "asbestosis," and mesothelioma, a cancer of the chest and abdominal cavities.

CFCs and other ozone-depleting chemicals have become a serious concern since the adoption of the Montreal Protocol on Substances that Deplete the Ozone Layer of 1987. As part of the United States' commitment to implementing the Montreal Protocol, the Clean Air Act (CAA) was amended by the US Congress to add provisions for the protection of the ozone layer by restricting the domestic production and importation in the US.[128]

Methods for detection and determination of air pollutants are listed at the Technology Transfer Network (TTN) Internet site through the Emissions Measurement Center (EMC) and the Ambient Monitoring Technology Information Center (AMTIC).[129,130] A compendium that lists and summarizes methods for the determination of toxic organic compounds in air is available online.[131] The toxic organic methods are also available in downloadable form.[132]

**Additional**

Pesticides are regulated under two federal statutes: FIFRA, and the Federal Food, Drug, and Cosmetic Act (FFDCA). The Food Quality Protection Act of 1996 (FQPA) amended FIFRA and

FFDCA to set tougher safety standards for pesticides and uniform requirements regarding foods. [133] The Office of Pesticide Programs has two indexes for analytical methods for pesticides. [134,135]

The Code of Federal Regulations also contains methods for analysis and can be accessed at two different Internet sites. [136,137] Some USEPA methods are easily available on the Internet in downloadable form. A table of these methods has been included in the appendix along with the corresponding Internet site addresses.

A nearly all-inclusive list of the USEPA methods, revised May 2000, contains the chemical or method name cross-referenced with USEPA report numbers, location in the Code of Federal Regulations (40 CFR), and media (if an electronic version is available). [138] A quick reference to USEPA methods with link connections to the methods or sources for purchase is online as well. [139]

A book by Keith provides a short description of USEPA methods listed by analytes. It includes only brief details on the sampling method for each and a much larger amount of information regarding the analytical method. [140]

Comparisons between different analytical methods (both organic and inorganic) and analyte cross-reference tables are provided in a handy book titled Guide to Environmental Analytical Methods. Tables with guidelines for methods on sampling, sample extraction, and cleanup are also included. [141]

Analytical methods used outside the US can sometimes be accessed through a nation's environmental protection or analytical standards Internet sites. The Environment Canada Internet site provides a search engine to locate selected environmental protection publications including reference methods and guidance documents. The number and title of the document, description, and purchase price are given in the search results. [142] A search by keyword or document number at the Dutch National Institute of Public Health and the Environment (RIVM) Internet site will yield detailed abstracts of available reports and order information for the full report. [143]

Standards Australia has a flexible "power search" for documents that allows the user to search by title, keyword, or standard number. The document number, title, and order info are provided in the search results. [144] The Environmental Protection Authority for the state of New South Wales, Australia, has two Internet sites that provide the list of approved methods for sampling and analysis for water pollutants and air pollutants. [145,146] The methods are listed in tables by the analytes of interest.

British Standards Online requires that Internet site users register first and then login before beginning any document search. The expanded search feature is impressive and allows wide-ranging search options in order to track down documents. Search results include the document number, title, and purchase price. [147]

## INSTRUMENTATION AND TECHNIQUES

A wide variety of instrumentation is often required for the analysis of environmental samples. Analytical Chemistry, a journal published by the American Chemical Society, is an incredibly valuable source of information for trends and current developments with instrumentation and analytical techniques. This journal has yearly review issues that alternate between "fundamental reviews" (1996, 1998, and 2000) and "application reviews" (1997, 1999, and 2001). [148] In the "fundamental reviews," techniques such as infrared spectroscopy or gas chromatography are covered.

Updates to the techniques, current research, and applications are often included in each of the reviews. The "application reviews" cover areas of chemistry such as environmental analysis, field analytical chemistry, and forensic science. These reviews are often subcategorized by instruments or techniques used or the types of samples analyzed. Searches of the table of contents for several years of Analytical Chemistry issues can be made at the journal's web site.

Results from a literature search of recent papers and reviews on topics, techniques and instrumentation are below. Recent Analytical Chemistry reviews have been included in this grouping.

Environmental Analysis

- Biennial review; developments in applied environmental analytical chemistry from November 1998 to October 2000; subcategories of SPME applications, air, water, and soil sample type analyses [149]
- Biennial review; developments from November 1996 to October 1998; categorized by matrix (air, water, soil, biological); technology cross-reference table [150]
- Biennial review; developments from November 1994 to October 1996; matrix subcategories for analysis applications; quality control and reference materials section [151]
- Trends in environmental analysis; developments in extraction methods, MS, and field-portable instrumentation [152]

Sample Preparation

- Review; extensive tables on techniques for preparation of both solid and liquid samples [153]
- Proper subsampling from field sample to the laboratory analysis sample; reducing mass and segregation errors [154]
- Selection of extraction technique for organic pollutants in environmental matrices; table summaries of analytes extracted by MAE, SFE, and PFE [155]
- Review; solventless sample preparation techniques; covers extraction with a gas stream, membrane extraction, SPE, and SFE [156]
- Comparison of extraction techniques for environmental solids [157]
- Evaluation of extraction recoveries for certain organometallic compounds in sediment and other matrices [158]

Air Analysis

- Review of research published from 1995 to 1998; air analysis by GC; table of sampling and injection techniques; table of stationary phases and analytes [159]
- Biennial review; methods for air pollutant analysis covering literature from January 1997 to December 1998; contents divided as gases and aerosols; applications to a variety of instrumentation [160].
- Review; analysis of organic compounds in air; massive tables of analytical methods for volatile organic compounds, aldehydes and ketones, semivolatile organic pollutants, polycyclic aromatic hydrocarbons, halocarbons, and isocyanates and amines [161]
- Review; sorbents used to trap volatile organic compounds from air [162]
- Analysis of process gases; overview of instrumentation and techniques, sampling systems, calibration and traceability, and data collection and processing [163]

Water Analysis

- Review covering developments in water analysis from 1999 to 2000 with a few significant 2001 references; contents categorized by pollutants [164]
- Review; methods for preconcentrating organic and inorganic compounds [165]

Atomic Spectrometry

- Annual review; atomic spectrometry update on analysis of environmental samples; categorized by media (air, water, soils, geological) [166]
- Annual review; combined atomic absorption and fluorescence with atomic emission spectrometry; covers literature from 1998 and 1999; topics include sample introduction, instrumentation and coupled techniques [167]
- Annual review; atomic spectrometry analysis for elements in air, water, soil and geologic materials; includes MS, XRF, AA, ICP-MS, AES, and other instrumentation [168]
- Trace element analysis of airborne particles; overview of methods with comparison between GFAAS, flame AAS, ICP-AES, and ICP-MS [169]
- Biennial review; cited papers from 1998 and 1999; developments with instrumentation and operation [170]
- Annual review; atomic spectrometry update on environmental analysis; topics categorized by sample media [171]
- Annual review; developments in atomic absorption and fluorescence spectrometry in 1997 and 1998 [172]
- Invited lecture on the future of atomic spectrometry in environmental analysis; discussions on sample preparation, instrumentation, detection power, speciation, and field portability; also includes nearly 200 references [173]
- Biennial review; publications from 1996 and 1997 on techniques of analytical atomic absorption; electrothermal atomization, flame atomic absorption and emission, laser techniques, and vapor-phase sample introduction are covered [174]

Capillary Electrophoresis (CE)

- Review; analysis of environmental samples; charts of fresh and salt water, wastewater, and industrial process water matrices; chart for soil, sediment, and biological samples [175]
- Review; status of CE for organic environmental pollutant determination based on papers published from 1997 to early 1999; excludes pesticides and inorganic pollutants from the review [176]
- Review; analysis of inorganic pollutants; environmental applications divided by sample media; analytes tables for atmospheric, aquatic, and soil samples [177]
- Review of references published mainly from 1995 to 1997; analysis of environmental samples; tables of sample matrices and ions [178]
- Review; separation and analysis of environmental pollutants [179]
- Biennial review; covers the period of October 1995 to October 1997; focus on significant developments in theory and practice of CE; advances in performance optimization, instrumental configuration, and detection strategies [180]
- Review; focused on methods developed since 1994 on the determination of pollutants; divided according to pollutant type; large table of environmental applications and corresponding references [181]

- Review; analysis of inorganic pollutants [182]
- Review; extensive table of anions, sample matrices and electrolyte system [183]

Gas Chromatography (GC)

- Biennial review; covers fundamental developments in gas chromatography published from 1998 and 1999; topics include adsorbents, phases, theory, and new technology [184]
- Biennial review; GC developments published in articles from 1996 and 1997 [185]
- Review; sample introduction techniques; GC-MS and GC-FTIR applications [186]
- Review; trace analysis of pesticides by GC; discusses differences between detectors and extraction techniques [187]
- Overview of sample introduction and sample preparation of volatile organic compounds for GC analysis [188]
- Automated GC system used by the Taiwan EPA for measuring ambient VOCs [189]

Gas Chromatography-Atomic Emission Detection (GC-AED)

- Empirical formula study of chlorofluorocarbons using GC coupled to atomic emission detection [190]

Gas Chromatography-Mass Spectrometry (GC-MS)

- Analysis of petroleum products within forensic science review [191]

High Performance Liquid Chromatography (HPLC)

- Biennial review; fundamental developments in column liquid chromatography equipment and instrumentation from October 1997 to October 1999; instrumentation, columns, and a variety of detectors are covered [192]
- Biennial review; developments in equipment and instrumentation from October 1995 through October 1997 [193]
- Biennial review; theory and methods in liquid chromatography from October 1995 through October 1997; topics include data analysis, biopolymer separations, affinity chromatography, ion chromatography, and preparative LC [194]
- Review of literature methods published from 1989 to 1996; vast chart of anions, stationary and mobile phases, methods [195]
- Review; determination of nitrite and nitrate in environmental samples [196]
- Review; determination of hazardous compounds (PCBs, dioxins, etc.) using reversed-phase HPLC; stationary phases discussed [197]

Ion Chromatography (IC)

- Review of articles published from 1997 to 1999 with some classic references; detailed chart of inorganic anions, matrices, columns, detectors; environmental applications [198]
- Review; sample preparation and separation techniques for IC and CE; numerous figures; comparison of advantages and disadvantages of IC and CE [199]
- Elemental analysis of airborne particles; included are tables on separation methods and filter media [200]

Inductively Coupled Plasma (ICP)

- Review; book selection on advances in ICP-Atomic Emission Spectrometry (ICP-AES) and ICP-Mass Spectrometry (ICP-MS); analytical capabilities and interferences of the two spectrometers; practical applications highlighting soil samples [201]

- USEPA methods and elements list; ICP-Optical Emission Spectrometry (ICP-OES) and ICP-MS technique comparison [202]
- Elemental speciation using ICP-MS interfaced to a liquid chromatograph [203]

Infrared (IR) Spectrometry

- Biennial review; articles published during 1998 and 1999; focus on 2D IR, combinatorial chemistry, and human health [204]
- Biennial review; covers published literature from November 1995 to October 1997 on aspects of IR spectroscopy relevant to chemical analysis; includes a section on environmental analysis [205]

Liquid Chromatography-Mass Spectrometry (LC-MS)

- Review; general overview of instrumentation; environmental applications [206]
- Review; current and future developments in pesticide trace analysis [207]
- Determination of herbicides in water; techniques and applications to herbicide analysis [208]
- Analysis of surface and waste water with atmospheric pressure chemical ionization [209]

Microwave Assisted Extraction (MAE)

- Review; extraction of environmental samples; tables for extraction of PCBs, pesticides, phenols, and organometallics in environmental matrices [210]
- Review; table comparing extraction techniques; tables for extraction of persistent organic pollutants and pesticides [211]
- Review; extraction of petroleum hydrocarbons from contaminated soils [212]

Mass Spectrometry (MS)

- Annual review; update on developments in instrumentation and methodology with atomic mass spectrometry [213]
- Annual review; advances in instrumentation, methodology, and in understanding of the fundamental phenomena of atomic mass spectrometry [214]
- Annual review; developments from 1997 and 1998; trends identified in each section [215]

Pressurized Fluid Extraction (PFE) - also known as Pressurized Liquid Extraction (PLE) or Accelerated Solvent Extraction (ASE)

- Review; extraction of persistent organic pollutants; tables of conditions found in the literature with matrices of soil, sediment, sewage sludge, dust, clay, fly ash, and biological tissue [216]
- Extraction of polycyclic aromatic hydrocarbons from soils [217]
- Extraction of PCBs from environmental samples as compared to SFE [218]
- Extraction of hydrocarbons from soils [219]
- Recovery of PCBs from organic matrix; comparison to Soxhlet extraction [220]

Supercritical Fluid Extraction (SFE)

- Review; methods, instrumentation, applications including environmental [221]
- Discussion of advantages, limitations of SFE [222]

Solid Phase Extraction (SPE)

- Review; environmental applications, coupling with capillary electrophoresis; table of analytes for SPE-CE [223]
- Review; method development, sorbents, coupling with liquid chromatography [224]
- Review; multi-residue analysis of organic contaminants in water [225]

- Review; historical to present day technical developments for SPE of organic pollutants in water [226]
- Review; functionalized cellulose sorbents for preconcentration of trace metals in environmental analysis [227]
- Review; recent developments in SPE based on polymer sorbents [228]
- Developments in SPE disks for use in environmental chemistry for analysis of trace organic compounds [229]

Solid Phase Microextraction (SPME)

- Review; extraction modes, fibers, and instrumentation interfaces [230]
- Review; determination of organic pollutants in environmental matrices; tables of published applications in air and liquid samples [231]
- Review; trace element speciation; table of species, sample type, and SPME method [232]

Ultra-Violet (UV) Spectrometry

- Biennial review; developments in ultraviolet and visible absorption spectrometry from January 1996 through October 1997; subject matter covered in categories of chemistry, physics, and applications [233]

X-Ray Spectrometry (XRS)

- Annual review of X-ray fluorescence spectrometry; developments over the period of 1999 to 2000; details on instrumentation and applications, including environmental [234]
- Analysis of ambient air samples; topics includes method comparison, sampling, interferences, and calibration [235]
- Annual review of X-ray fluorescence; covering papers published from 1998 to 1999 [236]
- Biennial review of X-ray spectrometry; literature from late 1998 to October 1999 [237]
- Annual review of X-ray fluorescence spectrometry; covers work published from 1997 to 1998; topics include instrumentation and applications [238]
- Biennial review; covering advances in X-ray spectrometry from November 1995 to the fall of 1997; contents include categories on excitation, detection, and quantitation [239]

Various extraction methods for environmental analysis are presented in a book by Dean. The book is divided by aqueous and solid samples and covers many techniques such as SPME, SFE, and MAE. Theoretical considerations and methods of analysis are discussed for the techniques and a chart comparing all the extraction techniques is at the end. [240]

Barceló has compiled a significant book in the "Techniques and Instrumentation in Analytical Chemistry" series. Chapters submitted by various authors fall into these key sections: Field Sampling Techniques and Sample Preparation, Quality Assurance, Reference Materials, and Chemometrics, Application Areas, and Emerging Techniques. [241]

# EVIDENCE PRESENTATION

## LINK ANALYSIS

Link analysis or criminal intelligence analysis has long been a tool of traditional criminal investigations. It has also become a method used to support criminal and civil environmental investigations. The various charting techniques used have covered many types of analysis, including the Traditional Link Analysis, Association Analysis, Telephone Record Analysis, Event and Activity Flow Analysis, Commodity Flow, Financial Analysis, Crime Pattern Analysis and Time/Event Analysis. Other chart types have also been developed to depict how an environmental crime was committed.

Link analysis charts have been proven to be an effective and successful tool in US trial presentations to depict a complex set of events along with the specific information related to the crime. These charts help the judge or jury understand the complex relationships which exist in environmental crime. Environmental crimes are often complex in nature and very difficult to follow, especially if the crime involves keeping track of the activities of many people and the timing of particular events, such as when various loads of waste are transported.

Anacapa Sciences provides training in traditional methods of link analysis using the link, event, activity, and commodity charting methods. [242] This basic method can easily involve rolls of paper and hundreds of "Post-it Notes." Anacapa has developed a computerized alternative to this in the Enhanced Criminal Network Analysis (ECNA) computer program.

A more powerful approach is provided by i2, Inc. [243] The Analyst's Notebook software package has two main tools for different types of analysis, the Link Notebook and the Case Notebook.

Link analysis is being used successfully by NEIC to connect complex details of environmental crimes. One use was with USEPA's reformulated gas initiative. This initiative required that the complex relationships between a company and employees be clearly defined and identified. For a high profile laboratory fraud case, NEIC developed timeline charts using i2's Case Notebook. After the defendant pled guilty, the timeline charts were submitted to the court for the sentencing phase to show the gravity of the fraud and illustrate the length of time that the fraud had been committed.

Another link analysis chart developed in a case against an environmental disposal company showed the relationship between the proposed method of waste disposal and the actual method of disposal. A corresponding link chart illustrated the telephone calls made by the defendants and helped to successfully prove the conspiracy. The guilty parties received stiff jail sentences and were forced to pay $1.27 million in clean-up costs.

## ENVIRONMENTAL SCIENCE AND THE COURTROOM

The end result of any actions performed by any forensic laboratory may be decided in a court of law. Data and scientific opinions will be admitted into evidence if the scientific information is relevant and reliable. The debate in the United States legal system over what scientific opinions and data may be included into evidence is ongoing. Understanding some of the factors that may shape the decision to accept or reject a scientist's testimony can benefit members of a forensic science community.

In US federal environmental enforcement cases, if defendants refuse to negotiate a settlement, the case proceeds to a trial in the federal court system. With a trial comes the challenge of understanding the scientific experts and scientific opinions presented in the case.

As a result of a US Supreme Court case referred to in short as *Daubert*, federal judges were given the responsibility of being the "gatekeeper" of scientific evidence in the courtroom. [244] The benefit of this ruling is that it prevents so-called "junk science" from being presented and possibly misleading a jury. (Juries composed of US citizens often serve as fact-finders.) In many environmental cases, a federal judge will hold some type of *Daubert* hearing before expert testimony will be heard.

In a *Daubert* hearing, both sides must present their best case regarding the scientific work and be prepared to defend the work as having a sound scientific footing. The opinions presented may be based on standard methods or on a novel application to established science. In addition to questioning by lawyers, judges often delve into the basis for expert opinions in order to find the answers to two key questions.

- <u>Is the opinion relevant</u>?

Does the opinion presented deal with the issues in the case? Do the scientific studies or research cited to support the opinion given have a direct relationship to the issues in the case?

- <u>Is the science reliable</u>?

Is the methodology that was used good science? (Was the method validated?) How were all aspects of the measuring process performed (from sampling to the laboratory analysis)? Were all the necessary QC actions taken to ensure the reliability of the data? Were established procedures for each action followed in the field, in the laboratory, and in all the steps in between? (Defensibility of field methods is no different from that of laboratory methods.) [245]

Two recent environmental crime cases involving NEIC demonstrate problems that can occur with determining the reliability of the science involved. One case necessitated that USEPA guidance be challenged and shown to be faulty. In another case, the company being prosecuted challenged their own data to show that it was unreliable and could not be used against them.

In the first case, the owner and operator of a fertilizer manufacturing company knowingly endangered his workers by exposing them to cyanide waste. A criminal investigation began as soon as USEPA learned of the illegal hazardous waste disposal activities that physically crippled and caused permanent brain damage to one of the employees. The employee had been sent into a 25,000 gallon storage tank to clean out the cyanide sludge inside without the required protective equipment and without telling the employee that the tank contained cyanide waste. Even though they asked direct questions regarding cyanide exposure, rescue workers and medical personnel were not told that the storage tank sludge contained cyanide.

Among other things, NEIC developed a storage tank model to demonstrate that the waste material in the storage tank was capable of generating the toxic gases in harmful levels. Additionally, because USEPA guidance on hazardous waste contained a flawed analytical method for measuring cyanide, other methods were employed to prove that the waste was hazardous. The *Daubert* challenge from the defense attacked the tank model and the waste sample collected from the storage tank on the premise that neither were representative of the actual circumstances in 1996.

An NEIC expert testified during the *Daubert* hearing, and was able to satisfy the judge that his opinion was based on reliable data and corroborating evidence. At trial, he presented his opinion that the waste was hazardous and explained how the evidence (testimony of others, NEIC sample analyses, and medical records) supported his opinion. The defendant was sentenced to a 17-year prison term, the longest sentence ever imposed for an environmental crime, and was ordered to pay $6 million in restitution to the injured employee. [246]

In the other case, the challenge raised by the defendant during the *Daubert* hearing was directed against the expert for the prosecution, as well as the defendant's own chemist and data. A major meat processing company and several of the company managers were charged with felony counts of conspiracy, illegal dumping of pollutants, and filing of false reports in violation of the federal Clean Water Act. [247,248] The company's discharge monitoring reports had been falsified to indicate compliance with the discharge permit provided to the wastewater treatment plant that treated waste from the company's slaughterhouse operation. Measurements taken to monitor discharges were recorded by the company chemist in two sets of books. One set contained the real numbers from testing and the other set contained the number fabricated for reporting to the USEPA.

The methodology used to obtain the test results was not challenged in the *Daubert* hearing. The company challenged their chemist's application of the method, claimed that the numbers could be higher or lower, and argued that their own chemist used no quality control and was incompetent and unreliable. An NEIC expert was required to examine the company's data and offered the opinion that it was of sufficient quality to prove permit violations. The court accepted that this data could be used in the trial.

The personal responsibility for quality work from all members in an environmental investigation and the relationship between the QA procedures and the actions actually performed now blends together to have a significant effect on actions within the courtroom. The scientific expert chosen to give his or her opinion on the scientific data and how it relates to the case must be someone with the experience, education, training, or "on-the-job" experience to address the issues. The expertise of the scientific witness is not always the focus of the strongest amount of scrutiny; it is quite often the execution of the methods involved in the measurement process (sample collection and handling, chain of custody, QA/QC, etc.) that is examined most closely. Therefore, all individuals involved in any part of the investigation must produce defensible work.

A thorough and well-referenced guidebook for legal professionals and scientists who may be providing expert testimony is the Scientific Evidence and Experts Handbook. [249] It is a compilation of eight chapters on topics such as "Pretrial Preparation in Scientific Cases," "Finding, Hiring, and Supporting Scientific Experts in Complex Scientific Evidence Cases," and "Scientific Evidence in Criminal Cases," written by litigators with years of experience in the courtroom. A year 2000 update to this handbook is also available. [250]

With the responsibility of being a "gatekeeper" for scientific and technical testimony in the courtroom, district court judges must now be able to perform inquiries into technical matters and evaluate scientific evidence. In order to assist judges in this potentially overwhelming task, a number of solutions have been proposed and will be tested for their usefulness and legal reliability in the coming years. [251] The Reference Manual on Scientific Evidence produced by the Federal Judicial Center is the easiest aid to obtain. Both editions of the manual can be downloaded from the Federal Judicial Center Internet site in whole or in separate sections. [252] Sections include discussions of statistics, toxicology and DNA evidence among many others.

Another aid to judges is the Court Appointed Scientific Experts (CASE) project developed by the American Association for the Advancement of Science (AAAS). [253] Concerns that a court-appointed expert might not be fully impartial or that such expert testimony could tip the balances in the legal system has many trial lawyers questioning the legal viability of this project. The Federal Judicial Center has indicated support for the project and will evaluate the project's usefulness after 5 years. [254]

## SELECTED TOPICS

### LABORATORY FRAUD

Laboratory fraud is defined as the deliberate falsification of analytical or quality assurance results, where failed method and contractual requirements are made to appear acceptable during reporting. [255] Laboratory fraud has also been defined as a deliberate mechanism, concealment, or falsification producing detrimental reliance on analytical results. [256] Laboratory fraud has historically been detected either by reports from disgruntled employees or electronic data audits. In both circumstances, the laboratory has already performed fraudulent work and the damage is done. [255]

In a paper presented at the USEPA 18th Annual National Conference on Managing Quality Systems for Environmental Programs, Worthington and Brilis discuss the assumption made by many data producers and users that analytical data are authentic when, in fact, the data are not authentic. There are a number of terms used to describe non-authentic data. Some people use the term "data integrity" to consider all issues. [257]

Lab fraud cases generally are brought forward by informants, disgruntled employees, or outside audits. [255] In 1999, the Center for Strategic Environmental Enforcement (CSEE), Criminal Investigation Division (CID), Office of Criminal Enforcement, Forensics, and Training performed an extensive review of all USEPA CID lab fraud cases that had been investigated from 1983 through 1998. The review identified 63 cases involving data falsification committed by a third party laboratory. [256] Third party laboratories are labs hired by companies to do their analytical testing (as opposed to performing tests using an in-house lab).

The extent of lab fraud cases has grown exponentially over the last few years. In the last 2 years alone, 11 new lab fraud cases have been opened in the United States. [256] This growing area of environmental crime is now being defined and addressed as a source of concern for enforcement agencies.

A literature review was conducted to examine the scope of the laboratory fraud problem. In a lab fraud case from 1995, Eureka Laboratories, Inc. was fined $1.8 million and two chemists were convicted of federal fraud charges related to the manipulation of lab results for federal contracts. The convictions came after the federal government suspended Eureka from contracting because of allegations of fraudulent practices. [258]

In another case, Donald Budd, the former owner of Texas Environmental Services of Beaumont, Texas, was sentenced to 6 years in federal prison after misrepresenting the lab's methods. The laboratory tested water for cities, refineries, and other companies. [259]

A slightly different type of laboratory fraud case involved a consulting company located in Portland Oregon. On June 14, 1996, the USEPA published an account of the fraudulent reporting of data by Robert Cyphers. [260] According to the USEPA statement, Cyphers, the former president and owner of UST Environmental Services, plead guilty to four felony counts involving the submission of written false statements to the government. As part of the plea agreement, he agreed to serve a recommended 30-month term of incarceration.

Cyphers had operated a company whose primary business was the removal of leaking underground storage tanks and the subsequent cleanup of contaminated soil and groundwater. He had submitted over a thousand fictitious laboratory analysis reports regarding the extent of soil and groundwater contamination to the Oregon Department of Environmental Quality. These reports are used by regulatory agencies to determine the degree of environmental contamination and cleanup needs necessary to protect human health and the environment. Based upon the few sites that have been re-sampled, analyses have determined that petroleum contamination still exists at the sites.

On January 7, 1998, Intertek Testing Services Environmental Services laboratory (ITS) made a voluntary disclosure that fraudulent practices were being conducted in their laboratory located in Richardson, Texas. [261] ITS disclosed that employees had been improperly manipulating QC data during the time period later determined to be 1991-1997. The manipulations included actions summarized with terms like "shaving," "juicing," and "time traveling" in order to make data appear to meet QC requirements. These practices affected hundreds of projects, thousands of clients, and hundreds of thousands of samples.

In another case, the USEPA Region 5 Laboratory, also known as the USEPA Central Regional Laboratory, was investigated for allegations of altering test results. A criminal investigation regarding these allegations was conducted by the US Department of Justice. The USEPA alerted federal prosecutors handling pollution cases, as well as scores of suspected polluters, that some data used in cases against polluters might be tainted. It was reported earlier that an unpublicized, 28-month investigation of one section of the USEPA's Central Regional Laboratory found that USEPA supervisors, along with private contractors in the lab's organic section, had mishandled some time-sensitive test samples by not initiating their analyses within required holding times. [262-264]

Worthington groups non-authentic data into two types: unintentional and intentional. Unintentional errors include those made during sample collection, calculation errors, or transcription errors. Intentional errors include the improper reuse of instrument calibration data, altering spiked samples to achieve the desired recovery level, and changing the date of analysis to suggest that samples were analyzed within holding times among many others. [257]

An internal USEPA memorandum discusses contributing factors for laboratory fraud. Managers such as USEPA officials, prime contractors, and laboratory owners may rationalize or even foster laboratory fraud when these factors exist.

- Ineffective oversight of laboratory data
- Shrinking market resulting in a focus on production over quality
- "One size fits all" approach to analytical requirements

According to the memo, lack of oversight has been identified as a problem in prior Office of Inspector General (OIG) and USEPA efforts. The second factor, a shrinking market, is an issue that cannot be influenced by the USEPA. The final condition, a "one size fits all" approach occurs in contracts that define specific quality assurance (QA) and quality control (QC) requirements. Although laboratories bidding on contracts are aware of the requirements, in specific cases they may view them as too stringent and cut corners to save money. [265]

Several publications have been written on laboratory fraud detection. In addition to reports by a disgruntled current or former employee, other sources of information leading to reports of lab fraud include data reviewers and data users, auditors and inspectors, and regulators. [256]

Another indication of fraudulent data reporting is an anomalously low bid on a contract. Bids that are 50% lower than every other bid indicate the possibility of lab fraud according to Stephen

Remaley, an investigator for the USEPA. Remaley describes the types of laboratory fraud as well as methods for detection of fraudulent practices. [266]

Simmons presented guidelines being developed by the California Military Environmental Coordination Committee for the prevention of laboratory fraud. The techniques which are being considered include double-blind proficiency test samples, audits, data validation, and electronic record audits. [258]

According to Worthington, an important step in processing non-authentic data is making and documenting decisions when the problem is first discovered. Also emphasized is the timely reporting of the potential fraud and the establishment of a reconciliation process. [257] Resources that can be used to assist in the detection of laboratory fraud and the subsequent reconciliation of data include laboratory employees, data users, and inspectors. [256]

A USEPA Region 9 paper contains a list of laboratory fraud terminology and provides a table containing a description of how to recognize each technique and real world examples of each type of laboratory fraud. The table also provides suggestions for further investigation for each technique detected. [255]

## CHEMICAL FINGERPRINTING

One useful forensic technique used in environmental investigations is chemical fingerprinting. Chemical fingerprinting is used to identify an unknown chemical or compound, or to trace contaminants back to a particular origin. For example, petroleum contamination can often be traced back to a particular refinery based on additives that are unique to that refinery or a study of metals in areas surrounding a smelter can point back to the smelter effluent as the cause of pollution.

Morrison reviews the use of chemical fingerprinting for petroleum hydrocarbons in recent articles. [267,268] Some items discussed include proprietary additives, alkyl leads, oxygenates, dyes, isotope analysis, and transport models. [267] Morrison also discusses the chemistry and transport of petroleum hydrocarbons and contaminant transport modeling in a recent book. A similar overview of chlorinated solvents is also included. [269]

Chemical fingerprinting as it relates to oils, gasoline, and diesel fuel is addressed by Bruya. He reviews the test methods and analyses used in identifying and matching samples, and provides a review on evaluating chemical data used in fingerprinting. Tables of production specifications with test methods and of petroleum compositions with references are provided. Metals analysis is mentioned briefly. [270]

Studies on the effects of lead-based gasoline to the environment and of the residual traces left in the environment after discontinuing the use of lead-based gasoline frequently use lead isotope analysis for source identification and age dating. The signature left by lead in gasoline is discussed in an article by Hurst and co-workers. [271]

Determining the sources of lead in the environment has been of world-wide interest. Lead isotope ratios have been studied in sediments in Scotland by Farmer, et al. to determine geochemical origins of lead and relative contributions from industrial and vehicle-exhaust emissions. [272] Gulson and co-workers detail a study on lead contamination that was centered in the intersection between a rural and an urban area in South Australia. Natural soil lead was considered along with orchard sprays, power stations, smelters, and gasoline additives. Isotopic ratios indicated that while the natural soil lead was the major component for soil below 30 cm, contamination from the tetraethyllead additive in gasoline was determined as the major component in surface samples.[273] A study of river waters flowing into San Francisco Bay, California from 1995 to 1998 traced the lead deposited in the drainage basin. Dunlap and colleagues saw a trend from leaded gasoline toward isotopic concentrations similar to inputs that occurred during hydraulic gold mining in 1853.[274]

Elemental ratios can also be used as a means of source identification. Monna and colleagues used lead isotope data and elemental ratios to study the lead isotope composition in lichens and aerosols to determine the impact of regional volcano activity.[275] Elemental association was also used by Rauch, et al. Lead and platinum group metals in road sediments were studied using laser ablation-inductively coupled plasma-mass spectrometry.[276]

Particle analysis is another way of tracing sources of pollutants. An older article by Linton, et al. examines the combined use of the scanning electron microscope with energy dispersive X-ray analysis, multi-element analysis, and X-ray powder diffraction to identify the sources of lead-containing particles in urban dusts. The techniques used in the lead tracing study are described and the strengths and limitations of the techniques are summarized.[277]

Particle source identification for air quality management is discussed by Hopke. A section covering basic principles and natural physical constraints leads into sections on source composition for airborne particles, chemical mass balance, multivariate calibration methods and factor analysis methods used for these studies.[278]

## ACCREDITATION OF ENVIRONMENTAL FORENSIC LABS

Due to some recent and unfortunate events, forensic laboratories have come under greater scrutiny for analyses and operations.[262-264,279-283] "Trustworthiness" and "responsibility" have been repeating themes as questions about the real quality behind scientific data are propagated in the press. The need to assure the public that a forensic lab is capable of providing legally defensible analyses has made accreditation the goal of many forensic laboratories at both the federal and state levels.[284-286]

Many accrediting bodies exist and while the basic goal of assuring the reliability of data from forensic laboratories is the same, there are variations between each that must be evaluated by each laboratory seeking a source for accreditation.

In the case of NEIC, this facility obtained accredited status for the laboratory's asbestos analysis program under the National Voluntary Laboratory Accreditation Program (NVLAP).[287,288] Since asbestos analysis accounts for only a portion of the total analyses conducted as part of the laboratory operations, additional accreditation in other laboratory functions was desired.

Accreditation of laboratory operations alone was insufficient to encompass all NEIC activities since the functions extend beyond sample analysis. Expert reports and expert witnessing, field investigations including sampling (single media or multimedia), facility audits, and advanced analytical applications also needed incorporation into an accreditation standard.

NEIC investigated the possibility of obtaining accreditation through the National Environmental Laboratory Accreditation Program (NELAP), the American Association for Laboratory Accreditation (A2LA), and the American Society of Crime Laboratory Directors/ Laboratory Accreditation Board (ASCLD/LAB) before reaching a viable accreditation standard agreement for center activities (laboratory, field, courtroom) with the National Forensic Science Technology Center (NFSTC).[289-292,285] The NEIC accreditation standard used elements of the ASCLD/LAB manual and met the requirements for ISO/IEC Guide 25 and ANSI/ASQC E4.

Sufficient funding to adequately meet the challenges of accreditation is a concern for forensic laboratories. Overall resources for the day to day implementation of accreditation standards need to be considered. A California state auditor report on forensic labs pointed out that money is needed not just for primary elements of accreditation (such as proficiency testing and court monitoring programs). Money also needs to be allocated for capital equipment replacement, facility improvements, management information systems, and forensic examiner training programs.[286] Time is another required resource. A drop in efficiency is to be expected as employee time is funneled into the production of documentation and reports.[293]

Writing an accreditation standard for a forensic laboratory and establishing a quality system to maintain the standard is not enough to ensure that quality scientific data is being produced unless each member of the lab takes responsibility for their part in the system. Rosecrance suggests the implementation of an ethics program in the laboratory.[294] In this article, the author covers the kinds of policies and actions that are needed to inform employees regarding unacceptable and fraudulent behavior. Additionally, a detailed table of unacceptable laboratory practices and the corresponding actions to avoid these problems is a valuable tool for manager and scientist alike.

Two interesting articles about the implementation of quality systems are found in the technical program of the 19th Annual National Conference on Managing Environmental Quality Systems.[295] MacMillan tells the success story and the means of quality system implementation for a small environmental testing laboratory. Of special note was the decision to hire a dedicated quality staff to document and formalize components of the program. The perspective of implementing a quality system on a state-wide level with a division of laboratories is given by Siders. In it, the author lists the fundamental and critical elements needed in a laboratory quality system, and the division-wide policies, standard operating procedures and manuals used to effect the laboratory accreditation.

The USEPA Quality System has some guidance documents that take into consideration the recent developments in the federal legal system regarding the admissibility of scientific evidence. A table of these documents and the Internet site locations are provided by Brilis, et al.[296] Additionally, the authors have provided a detailed list of criteria to consider in every stage of an environmental investigation in order to ensure that quality is maintained and is consistent.

A 1996 book by Günzler provides some details on different accreditation systems world-wide. Many authors contributed brief descriptions of accreditation systems in different nations. Additionally, the book contains chapters on quality assurance, traceability, and reference materials among other things.[297]

The US environmental testing industry has joined with state regulators to form the National Environmental Laboratory Accrediting Conference (NELAC). NELAC has published a series of standards and within the last year has accredited its first group of private laboratories.[298]

## CONCLUSIONS

Key points relevant to environmental forensics investigations and the corresponding aspects are highlighted below.

- Information systems for the environmental forensic investigator are booming with increasing amounts of data being added every day regarding chemicals, fate models, and financial/corporate connections. Two substantial encyclopedias, the Kirk-Othmer Encyclopedia of Chemical Technology and the Ullmann's Encyclopedia of Industrial Chemistry, provide details on engineering fundamentals, plant processes, and industrial chemicals.
- Many Internet sites within the USEPA provide extensive details about environmental crime scene investigations. Information available for investigators in the field include references to standards and methods, example documentation and reports, sampling techniques, and guides on field measurements. Several other Internet sites include details on laboratory analysis, some with downloadable methods available to the user. The environmental protection agencies of many countries provide search engines on their Internet sites for reference methods and guidance documents.
- With the increasing expansion of computer systems and software, case agents for environmental criminal investigations face a new challenge. One recommended solution to the problem of electronic evidence in an investigation is to include computer forensic analysts as part of an investigative team, like engineers, geologists, or chemists. An alternate approach, to train the agent in computer forensics, may be time-consuming and may be insufficient to stay aware of rapid changes in computer technology.
- In the US, laboratory fraud has become an increasing part of environmental crime investigations. Conditions that can encourage laboratory fraud to occur are the ineffective oversight of laboratory data, a shrinking consumer market that reinforces a focus on production over quality, and an approach to analytical requirements that assumes that QA/QC can be the same for all analyses. Fraud hotlines and techniques such as double-blind proficiency testing, data validation, and electronic record audits are among the suggestions for the prevention of laboratory fraud.
- Accreditation has now become a key focus of environmental forensic laboratories. Important considerations for achieving accredited status include planning sufficient funding to support the elements of accreditation (such as proficiency testing, facility improvement, and management information systems) and planning in sufficient time resources to develop documentation and support changes in the organizational and functional structure.
- For environmental forensic organizations that include more than just a laboratory, elements other than the lab that are involved in the investigative process should also be considered for inclusion in an accreditation standard. Elements such as field sampling, evidence custody and preservation, and proper documentation can affect the prosecution of a criminal case and should be included in the quality management provided by properly designed accreditation standard.

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# APPENDIX

## TERMINOLOGY AND PUBLICATIONS

Several lists of environmental and environmental forensics terms and abbreviations exist. Details about USEPA publication codes and sources for publications are also available to help the investigator.

- Morrison's book Environmental Forensics: A Glossary of Terms has a very long list of acronyms and abbreviations as a chapter before the section on environmental forensics terms.
  Morrison RD. Environmental Forensics: A Glossary of Terms. Boca Raton (FL): CRC Press, 1999.
- USEPA Terminology Reference System. http://www.epa.gov/eimd/trs/production/ (accessed June 2001). The Terminology Reference System is a collection of environmental terms used by the USEPA. Terms and the definitions can be found by browsing or by performing a keyword search.
- USEPA National Service Center for Environmental Publications - Understanding "EPA Speak." http://www.epa.gov/ncepihom/epaterm.htm (accessed June 2001). Understanding "EPA Speak" has a section on "Terms of the Environment" that has a browse option for terms and abbreviations and acronyms.
- NTIS Web Site Home Page. http://www.ntis.gov/ (accessed June 2001). The US Department of Commerce National Technical Information Service is a centralized source for scientific, technical and business related government publications.
- US Government Printing Office. http://www.gpo.gov/ (accessed June 2001). The US GPO is another publications source for the United States federal community.
- USEPA National Service Center for Environmental Publications - NSCEP, USEPA Publication Numbering System. http://www.epa.gov/ncepihom/nscep-codes.htm (accessed June 2001). The codes used to refer to USEPA reports and publications are deciphered at the National Service Center for Environmental Publications with the USEPA Publication Numbering System. A table to convert code numbers and alpha descriptors is provided.
- Information Sources - USEPA Publications. http://www.epa.gov/epahome/publications.htm (accessed June 2001). A list of sources for USEPA publications is given at the USEPA Publications Internet site. It has a link to an Internet site with more information on searching for or purchasing documents.

## SUPPLEMENTAL INTERNET SITES

General

- European Union Policies - Environment. http://europa.eu.int/pol/env/index_en.htm (accessed June 2001). Site contains an index to information from the European Union on environmental issues.

- Environmental Agencies of the World. http://www.worldbankgroup.org/nipr/epas.htm (accessed June 2001). Lists of the agencies in most countries primarily responsible for environmental issues at the national level are available here.
- NIPR: New Ideas in Pollution Regulation Home Page. http://www.worldbankgroup.org/nipr/ (accessed June 2001). Information for researchers, government officials, and citizens interested in understanding and improving control of industrial pollution, especially in developing countries. The site focuses on materials produced by the World Bank's Economics of Industrial Pollution Control Research Project.
- The Regional Environmental Center for Central and Eastern Europe. http://www.rec.org/ (accessed June 2001). This is a non-advocacy, non-profit organization that assists in solving environmental problems in Central and Eastern Europe (CEE).
- Environment Canada - CEPA Environmental Registry. http://www.ec.gc.ca/ceparegistry/default.cfm (accessed June 2001). The CEPA Environmental Registry is a comprehensive source of public information relating to activities under the Canadian Environmental Protection Act, 1999.
- Joint Research Centre. http://www.jrc.org/ (accessed June 2001). Created by the European Commission, all eight institutes of the Joint Research Centre (JRC) are listed on this site. The Environment Institute (EI) conducts research in support of EU policies for the protection of the environment and the citizen.
- The Air Pollution Exchange - News. http://www.uea.ac.uk/~e044/apex/news.html (accessed June 2001). New Directions appears in the international journal Atmospheric Environment as an invited or contributed column reporting on all aspects of the atmospheric sciences. The articles are written in a popular style, not as scientific papers, but are nevertheless authored by experts in their field. A panel of members from the journal's editorial board reviews the articles. The columns are also featured in Atmospheric Environment journal.

Legal and Regulatory

- EHS Internet Library - Foreign Governments. http://www.safetymgmt.com/Foreign.htm (accessed June 2001). Links to foreign government sites and their environmental, health and safety regulatory information services.
- Monash University Law Library - Subject Guides, Environmental Law. http://www.lib.monash.edu.au/law/oldsubject.htm#Environ (accessed June 2001). Developed by the Monash University Law Library of Australia, this site includes a variety of links pertinent to Environmental law. It is international in scope.

Gathering Information

- ATSDR - HazDat Database. http://www.atsdr.cdc.gov/hazdat.html (accessed June 2001). HazDat, the Agency for Toxic Substances and Disease Registry's Hazardous Substance Release/Health Effects Database, is the scientific and administrative database developed to provide access to information on the release of hazardous substances from Superfund sites or from emergency events and on the effects of hazardous substances on the health of human populations.

Methods and Method Selection

- USEPA Information Sources - Environmental Test Methods and Guidelines. http://www.epa.gov/epahome/standards.html (accessed June 2001). Environmental test methods and guidelines from the United States Environmental Protection Agency.
- USEPA New England Library. http://www.epa.gov/region01/oarm/links.html (accessed June 2001). More links to sources of United States Environmental Protection Agency test methods on the Internet.
- SamplePrep Web at Duquesne University. http://www.sampleprep.duq.edu (accessed June 2001). This Internet site on sample preparation was developed by Duquesne University of Pittsburgh, Pennsylvania. It contains information and advice regarding analytical sample preparation, speciated analysis, trace analysis and microwave chemistry.

Reference Materials

- NIST SRM Catalog - Welcome Page. http://ois.nist.gov/srmcatalog/ (accessed June 2001). This Internet site from the United States National Institute of Standards and Technology (NIST) provides technical and ordering information for Standard Reference Materials (SRMs) and Reference Materials (RMs) that are currently available through the NIST Standard Reference Material program.
- NRC - Certified Reference Materials (CRMs)/Standard Reference Materials (SRMs). http://www.ems.nrc.ca/ems1.htm (accessed June 2001). Reference materials from the Institute for National Measurement Standards of the National Research Council of Canada.
- Reference Materials - Particle & Surface Sciences. http://www.pss.aus.net/products/ref_mat.html (accessed June 2001). Laboratory of the Government Chemist (LGC), is a UK organization which acts as a central supply for Certified Reference Materials (CRMs) from around the world. This site provides an Internet-based search for CRMs.

Computer Forensics

- United States Department of Defense, Computer Forensics Laboratory. http://www.dcfl.gov/ (accessed June 2001).
- US Department of Justice, Cybercrime. http://www.usdoj.gov/criminal/cybercrime (accessed June 2001).
- Computer Forensics Tool Testing Project Web Site. http://www.cftt.nist.gov/ (accessed June 2001). This project is supported by the US Department of Justice's National

Institute of Justice (NIJ), federal, state, and local law enforcement, and the National Institute of Standards and Technology (NIST) to promote efficient and effective use of computer technology in the investigation of crimes involving computers.

- Computer High Tech Crime and Related Sites. http://members.aol.com/crimejust/hightech.html (accessed June 2001).
- Royal Canadian Mounted Police, Computer and Telecommunication Crime. http://www.rcmp-grc.gc.ca/html/cpu-cri.htm (accessed June 2001).
- American Society for Industrial Security (ASIS). http://www.asisonline.com (accessed June 2001).

Many companies are now providing computer forensic work. Some work for private corporations and some are under contract to law enforcement agencies. A few of these companies are listed below.

- New Technologies, Inc. http://www.forensics-intl.com (accessed June 2001).
- Computer Security Institute. http://www.gocsi.com/ (accessed June 2001).
- Computer Forensics, Ltd. http://www.computer-forensics.com/ (accessed June 2001).
- Computer Forensics, Inc. http://www.forensics.com (accessed June 2001).
- Electronic Evidence Discovery. http://www.eedinc.com (accessed June 2001).
- Ontrack Data International. http://www.ontrack.com (accessed June 2001).
- Vogon International Data Recovery and Forensic Computing. http://www.vogon.co.uk (accessed June 2001).

Accreditation

- ISO 17025 (Guide 25) Home Page. http://www.microserve.net/~iso25/ (accessed June 2001). General requirements for the competence of calibration and testing laboratories by ISO/IEC/EN 17025 (formally ISO Guide 25 & EN45001). Site includes an international listing of accreditation bodies and standards organizations with links to their Internet sites.

**Table**

**DOWNLOADABLE USEPA METHODS ONLINE**

| TOPIC | METHODS OR INFORMATION |
|---|---|
| Environmental Analysis | Choosing the correct procedure: Ch. 2* |
| Sample Preparation | Inorganic analytes: Ch. 3.2*<br>Organic analytes: Ch. 4.2* |
| Atomic Absorption (AA) | Method 7000A, Table 1 lists detection elements;<br>7000 Series Methods* |
| Gas Chromatography (GC) | Methods, analytes listed in Ch. 2, Tables 4-19*<br>515.3, 515.4, 556, and 556.1†<br>601 to 604, 606 to 612‡ |
| GC-FTIR | 8410 and 8430* |
| Gas Chromatography-Mass Spectrometry (GC-MS) | Methods and analytes listed in Ch. 2, Tables 20 – 23;*<br>Method 526;† 613, 624, 625, 1624, and 1625‡ |
| High Performance Liquid Chromatography (HPLC) | Methods and analytes listed in Ch. 2, Tables 24 – 31;*<br>Method 532;† 605 and 610‡ |
| Infrared (IR) Spectrometer | 8440* |
| Ion Chromatography (IC) | 9056 and 9057,* 300.0, 300.1, 314.0 and 317.0† |
| ICP-AES | 6010B, detection elements in Table 1* |
| ICP-MS | 6020, detection elements in Table 1* |
| Polarized Light Microscopy (PLM) | EPA/600/M4-82-020§ |
| X-Ray Fluorescence (XRF) | 9075* |

* USEPA: SW-846 Online. http://www.epa.gov/SW-846/main.htm (accessed June 2001).

† Analytical Methods Developed by the Office of Ground Water and Drinking Water. http://www.epa.gov/safewater/methods/sourcalt.html (accessed June 2001).

‡ Methods for Organic Chemical Analysis. http://www.epa.gov/waterscience/Tools/guide/methods.html (accessed June 2001).

§ 2000 CFR Title 40, Volume 27, Chapter I, Part 763, Asbestos. http://www.access.gpo.gov/nara/cfr/ (accessed June 2001).