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Environmental Forensic Chemistry and Sound Science in the Courtroom

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ARTICLES

ENVIRONMENTAL FORENSIC CHEMISTRY AND SOUND SCIENCE IN THE COURTROOM

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INTRODUCTION

Liabilities associated with environmental activities are steadily increasing.[1] To resolve many of these issues, representative data of known quality and integrity must be used. Unfortunately, these data attributes are not always easily measurable.[2] Furthermore,

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1. *See, e.g.*, Ronald G. Aronovsky, *Liability Theories in Contaminated Groundwater Litigation*, 1 J. ENVTL. FORENSICS 97 (2000) (providing a detailed case law account regarding the growth of groundwater contaminant litigation in both federal and state court, focusing on RCRA and CERCLA actions). Disputes regarding contaminated sites have led to an explosion of litigation. *Id.* at 97. *See also* David R. Tripp & Stacy J. Stotts, *Cases in 1998, in* SOLID AND HAZARDOUS WASTE COMMITTEE, AMERICAN BAR ASSOCIATION 18TH ANNUAL RCRA/CERCLA AND PRIVATE LITIGATION UPDATE (Dec. 1998) (listing the various cases brought in 1998).

2. *See generally* John P. Maney & A. Dallas Wait, *The Importance of Measurement Integrity*, 3 ENVTL. LAB. 20 (1991) (discussing the importance of using data with integrity for environmental measurements).

data collection activities themselves may have been poorly conceived and the resulting data incorrectly interpreted.[3] Confounding this situation is the occasional deliberate corruption of data, a problem which has been and continues to be an issue in science generally,[4] and more specifically an issue in environmental studies.[5] Even if data are reliable, the admissibility of the data in court and expert testimony predicated on that data might be challenged.[6]

The purpose of this Article is to provide insight into the generation of environmental data which, to preclude the alarming problems alluded to above, reliably address the data quality objectives of an investigation. As such, this Article discusses the elements of producing data of sufficient quality and integrity to be admissible in court within the context of environmental forensic investigations. Part I describes environmental forensics and the tools used by forensic scientists to determine sources of contamination. Part II sets forth the objectives behind data quality and how data quality is measured. Part III discusses the importance of data integrity and the dangers of data fraud. Finally, Part IV provides information regarding data admissibility at trial, and specifically analyzes case law governing expert testimony and its admissibility.

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3. *Id.* at 22 (stating that impaired results may result from improper choice of analysis methods).

4. Over the years, faulty science has been published for such "breakthroughs" as polywater and cold fusion. *See* Ira S. Krull, *Reproducibility, Reproducibility and Reproducibility*, 32 AMER. LAB. 6, 8 (2000) (discussing how failure to repeat an experiment, thereby lacking 100% certainty, can be damaging and provide wrong results). Many crime labs suffer from using unsound science techniques. *See* Barry Scheck New York Times, May 11, 2001 at A31.

5. The literature is replete with examples, particularly in the 1990s. *See* discussion *infra* Part III.

6. *See* GEORGE M. BRILIS & JEFFREY C. WORTHINGTON, U.S.ENVTL. PROTECTION AGENCY, SCIENCE IN LAW AND COURTROOM DECISIONS ON SCIENCE – A HISTORICAL PRIMER, 17TH ANNUAL NATIONAL CONFERENCE ON MANAGING ENVTL. QUALITY SYSTEMS, § T23, at 3 (1998) (describing challenges based on relevance and authenticity and the Federal Rules of Evidence that are used in disputes).

Environmental chemistry techniques used by forensic investigators are used to highlight the discussion.

I. ENVIRONMENTAL FORENSICS

In recent years, environmental managers and their legal counsel have grown to rely on forensics as a means to allocate liability in environmental dispute resolution.[7] Environmental forensics helps to answer questions such as: Whose contamination is it? How much did different parties contribute? When did the release occur? How did it occur? These questions typically arise in disputes between potentially responsible parties ("PRPs"),[8] between PRPs and regulators or insurers, or between plaintiffs and defendants in a toxic tort action.[9]

To address these liability issues, environmental forensic investigators use interdisciplinary approaches involving, in part, forensic chemistry, chemical fingerprinting, hydrogeology, stratigraphy, geochemistry, chemometrics, and site history.[10] Forensic chemistry is rooted in criminal investigations.[11] In the

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7. *See generally* Robert D. Morrison, ENVTL. FORENSICS, PRINCIPLES & APPLICATIONS (2000) (describing numerous techniques which have been successfully used to resolve environmental liability issues). A recently organized publication, JOURNAL OF ENVTL. FORENSICS, documents the application of environmental forensic techniques, often in the context of case studies.

8. For example, adjacent site owners or successive owners of the same site.

9. *See* James H. Clarke et al., *Envtl. Forensics*, 10 ENVTL. PROTECT. 49, 52 (1999) (reminding witnesses to communicate to a judge and jury).

10. *See* Scott A. Stout et al., *Envtl. Forensics – Unraveling Site Liability*, 32 ENVTL. SCI. TECH. 260A, 260A (1998); *see also* Neil M. Ram et al., *Envtl. Sleuth at Work*, 33 ENVTL. SCI. TECH. 464A, 467A (Table 1) (1999) (describing the forensic tools an environmental expert uses to detect details of source contamination); Clarke, *supra* note 9, at 49 (stating that since environmental forensics analysis is multi-disciplinary, it is also controversial).

11. *See, e.g.*, Samuel M. Gerber & Richard Saferstein, MORE CHEMISTRY AND CRIME (1997).

1950s and 1960s, advances in the science of substance analyses provided prosecutors with new tools for uncovering criminal actions.[12] Yet the impetus for forensic chemistry investigations relating to the environment did not occur until applicable regulations were promulgated in the 1970s.[13]

Also in the 1970s, dramatic breakthroughs in analytical chemistry technology, such as gas chromatography and mass spectroscopy, provided investigators with the ability to analyze selectively (both qualitatively and quantitatively) for compounds with unique attributes.[14] At the same time, quality assurance systems were being designed to produce data that could withstand both scientific and litigation scrutiny and, therefore, be admissible in court. The Safe Drinking Water Act of 1974,[15] and the subsequent 1976 Consent Decree[16] between the United States Environmental Protection Agency ("EPA") and several environmental groups, promoted regulatory analytical chemistry methods associated with quality control procedures which results in demonstratively sound

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12. Research documenting some of these scientific advances was published in the mid-1950s in the JOURNAL OF FORENSIC SCIENCE, and a few years later in the JOURNAL OF FORENSIC SCIENCE SOCIETY. Numerous texts on forensic science were published soon after. *See, e.g.*, F. Lundquist, METHODS OF FORENSIC SCIENCE (1963); R. Saferstein, FORENSIC SCIENCE HANDBOOK (1982).

13. The formation of the U.S. Environmental Protection Agency in 1970 provided the platform for comprehensive environmental regulations at the federal level. Numerous texts have been published summarizing environmental statutes. *See, e.g.*, W.H. Rodgers, ENVTL. LAW (2nd ed. 1994); ENVTL. LAW REP., ENVTL. LAW DESKBOOK (6th ed. 2000).

14. *See* A. Dallas Wait, *Evolution of Organic Analytical Methods in Envtl. Forensic Chemistry*, 1 J. ENVTL. FORENSICS 37, 37 (2000) (enabling forensic scientists to produce sound scientific data that is admissible in court).

15. 42 U.S.C. § 300(f) *et seq.* (1994 & Supp. IV 1998).

16. *See* Wait, *supra* note 14, at 37 (explaining that the 1976 Consent Decree between the EPA and several environmental groups promotes regulatory chemistry methods associated with quality control will help produce data with integrity).

scientific data.[17] By 1977, federal regulations specifically required the use of USEPA-approved analysis methods.[18] Accordingly, in response to the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA") regulations,[19] the Superfund Contract Laboratory Program ("CLP") was established in 1980 as a result of several unsuccessful attempts to recover damages from PRPs due, in part, to poor forensic practices.[20] "The CLP was envisioned as a strict laboratory protocol with aggressive contractual obligations," constituting a forensic document detailing all sampling and analysis activities.[21] Requirements for evidence files have been defined in the EPA's CLP Statement of Work for contract laboratories,[22] as well as by EPA's National Enforcement Investigation Center.[23]

An environmental forensic program is usually designed to look for unique site or contaminant attributes which identify the responsible party(ies). To accomplish this successfully, there needs to be some understanding of the historical activities at the site, including industrial activities, waste handling practices, and

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17. *See generally* J.J. Lichtenberg, American Society of Testing and Materials ("ASTM") Special Technical Publication No. 686, *Colloquium – The Impact of the Consent Decree on Analytical Chemistry in Industry,* in MEASUREMENT OF ORGANIC POLLUTANTS IN WATER AND WASTEWATER 9 (1978) (describing some of the procedures for analyzing pollutants).

18. Federal Water Pollutant Control Act (Pub. L. No. 92-500 § 304(H)) and the Interim Drinking Water Regulations.

19. 42 U.S.C. 9601 *et seq.* (1994 & Supp. IV 1998).

20. *See* Bruce K. Wallin et al., *Minimizing Data Quality Liability*, 6 ENVTL. LAB. 19, 20 (1994).

21. *Id.* at 20.

22. *See, e.g.,* U.S. Envtl. Protection Agency, *Statement of Work for Organics Analysis Multimedia Multi-Concentration,* IFB Series WA-87J001, WA-87J002, and WA-87J003 (1987). *See also* U.S. Envtl. Protection Agency, *EPA Contract Laboratory Program Statement of Work for Organics Analysis*, OLM 04.2 (1999).

23. *See generally* OFFICE OF ENFORCEMENT AND COMPLIANCE MONITORING, U.S.ENVTL. PROTECTION AGENCY, *National Enforcement Investigations Policies and Procedures.* National Enforcement Investigation Center, EPA-330/9-78-001-R (1986).

accidental spills.[24] Using this information, an experienced forensic chemist can often devise an analytical chemistry program focused on unique marker compounds and/or mixture "fingerprint patterns" which develop linkages between contaminants and contributing parties.

Regulatory analytical chemistry methods initially promulgated in the 1970s and 1980s focused on certain target compounds which were selected for regulatory control, in part, by their prevalence in the environment and perceived potential for harm to public and ecological health.[25] Today these methods are typically used to investigate the presence and extent of contamination, to classify wastes, to aid in the design and evaluation of remediation alternatives, and to monitor cleanup and disposal activities. Although these types of target-analyte methods may be useful to today's environmental forensic chemist, they are often inadequate to determine the source, fate and transport chemistry being forensically investigated. In effect, regulatory target analytes, considered rather ubiquitous in the environment, often do not satisfy the unique distribution attributes sought by the forensic chemist.

Marker compounds may either be biomarkers, which are the biochemical products of organisms that have survived in the environment with little or no transformation, or synthetic organic chemicals indicative of select manufacturing processes. Biomarkers are typically used to differentiate sources of petroleum hydrocarbon products.[26] Synthetic organic markers are often used to identify

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24. For example, see A.J. Gravel, *in* IBC USA 3RD ANNUAL EXECUTIVE FORUM ON ENVTL. FORENSICS, *Developing the Historical Case: Sources & Research Techniques Aimed at Obtaining Hard-to-Get Historical Documents Critical to Your Case* (2000) for helpful methods to develop a historical case of an environmental site.

25. *See generally* Ronald A. Hites & William L. Budde, *EPA's Analytical Methods for Water: The Next Generation*, 25 ENVTL. SCI. TECH. 998 (1991) (summarizing regulatory methods for analyzing water during this time period).

26. *See generally* Kenneth E. Peters & J. Michael Moldowan, THE BIOMARKER GUIDE (1993) (providing details on using biomarkers for petroleum source identification). *See also* R. Paul Philip & C. Anthony Lewis, *Organic Geochemistry of Biomarkers*, 15 ANN. REV. EARTH PLANET. SCI. 363 (1987).

sources of chemical waste products. For example, the additive methyl tert-butyl ether ("MTBE"), an environmental contaminant of recent notoriety,[27] has been used as an octane enhancer in gasoline since the late 1970s.[28] Until recently,[29] forensic chemists have been using this marker compound to differentiate modern gasoline contamination from older gasoline formulations.[30] Most MTBE litigation to date has focused on drinking water supply contamination.[31] For example, researchers evaluated the sources of MTBE in Donner Lake, California, a multiple-use lake located in the Sierra Nevada Mountains, which contained highway runoff,

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27. *See, e.g.*, James E. McCarthy & Mary Tiermazin, CONGRESSIONAL RESEARCH SERVICES ENVIRONMENT AND NATURAL RESOURCES POLICY DIVISION, *CRS Report to Congress, MTBE in Gasoline: Clean Air and Drinking Water Issues* (Mar. 24, 1998). The Congressional Research Service of the Library of Congress has delineated many of the environmental MTBE contaminant issues for Congress.

28. James M. Davidson & Daniel N. Creek, *Using the Gasoline Additive MTBE in Forensic Environmental Investigations*, 1 J. ENVTL. FORENSICS 31, 31 (2000) (reporting that in 1979, MTBE was first used as a gasoline additive, predominantly in higher grades of gasoline).

29. *See* Gary A. Robbins et al., *Occurrence of MTBE in Heating Oil and Diesel Fuel in Connecticut*, 20 GROUNDWATER MONITORING & REMEDIATION 82, 82-83 (2000). Researchers have recently found that MTBE may also be present in heating oil and diesel fuel, although it is only intentionally added to gasoline. *Id.* This discovery may complicate the forensic investigator's interpretation of sources of MTBE on a site-specific basis.

30. Davidson & Creek, *supra* note 28, at 31 (stating that MTBE data can be used for forensic investigations of subsurface gasoline spills).

31. *See, e.g.*, City of Santa Monica v. Shell Oil, No. 313004 (Cal. Super. Ct. 1987). On June 19, 2000, Santa Monica sued manufacturers and distributors of MTBE and gasoline containing MTBE for unspecified damages related to the contamination of the city well field. *Id. See also* England v. Atlantic Richfield, No. 00-L-331 (Ill. Cir. 2000), the first multi-state class action to deal with the problem of groundwater contamination by MTBE.

atmospheric deposition, and effluents from lake usage.[32] It was determined that motorized watercraft were the main source of the MTBE in the lake.

An example of a more complex forensic marker compound investigation is a study that evaluated sources of organic matter impacting various watersheds.[33] Targeted sources included wastewater treatment plant effluent, agricultural and feedlot runoff, urban runoff, and wildlife.[34] Using markers such as fecal steroids, caffeine, consumer product fragrance materials, and petroleum and combustion byproducts, the researchers were able to qualitatively assess the impact of contaminant sources on receiving waters throughout the United States.[35] Isotope analyses of organic compounds can also be valuable marker measurements for discerning sources of contaminants.[36]

Nonorganic substances can also be used effectively as marker compounds. For example, researchers conducted a multi-element, multi-media study of toxic elements in the vicinity of two secondary lead smelters.[37] Characteristic ratios of certain trace metals[38] showed

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32. *See* John E. Reuter *et al.*, *Concentrations, Sources, and Fate of the Gasoline Oxygenate Methyl tert-Butyl Ether (MTBE) in a Multiple-Use Lake*, 32 ENVTL. SCI. TECH. 3666, 3669-3670 (1998) (describing the effects of these sources on the lake).

33. *See generally* Laurel J. Standley et al., *Molecular Tracers of Organic Matter Sources to Surface Water Resources*, 34 ENVTL. SCI. TECH. 3124 (2000).

34. *Id.* at 3124.

35. *Id.*

36. *See* E.M. van Warmerdam et al., *Stable Chlorine and Carbon Isotope Measurements of Selected Chlorinated Organic Solvents*, 10 APPLIED GEOCHEM. 547, 547 (1995) (finding that environmental isotopes provide information about the sources and transformation of organic compounds in groundwater systems). *See also* SCOTT A. STOUT ET AL., DIVISION OF ENVTL. CHEMISTRY, AM. CHEMICAL SOC'Y, SOURCE DIFFERENTIATION OF INDIVIDUAL CHLORINATED SOLVENTS DISSOLVED IN GROUNDWATER USING COMPOUND SPECIFIC CARBON ISOTOPIC ANALYSIS, 38 PREPRINTS OF EXTENDED ABSTRACTS 2 (1998).

37. *See generally* David E. Kimbrough & I.H. Suffet, *Off-Site Forensic Determination of Airborne Elemental Emissions by Multi-Media Analysis: A Case Study of Two Secondary Lead Smelters*, 29

a relationship between the concentration of the elements in the solid materials processed in the plants, in materials and soils on-site, in the soils off-site, and in the air around the plants.[39] In another case, investigators have shown that rare earth elements[40] can be useful markers for demonstrating anthropogenic sources in coastal marine sediments.[41]

A valuable tool in discerning the release time of a contaminant can be the presence of marker compounds along with defined periods of time in which they were manufactured or used in product formulations.[42] For instance, in the environmental insurance industry, policies are often structured with a time trigger directly related to the occurrence of a contaminant release.[43]

ENVTL. SCI. TECH. 2217 (1995) (describing the study, its analysis and its conclusion).

38. Trace metals included lead, antimony, arsenic, cadmium, and silver. *Id.* at 2219.

39. *Id.* at 2220.

40. *See* I. Omez et al., *Rare Earth Elements in Sediments off Southern California: A New Anthropogenic Indicator*, 25 ENVTL. SCI. TECH. 310, 310 (1991). Rare earth elements include lanthanum (La), cerium (Ce), neodymium (Nd), samarium (Sm), europium (Eu), gadolinium (Gd), dysprosium (Dy), erbium (Er), ytterbium (Yb), and lutetium (Lu). *Id.*

41. *Id.* at 310, 315.

42. *See generally* Robert D. Morrison, *Critical Review of Envtl. Forensics: Part II*, 1 J. ENVTL. FORENSICS 175 (2000) (describing various markers that enable forensic scientists to determine the timing). *See also* Robert D. Morrison, *Critical Review of Envtl. Forensics: Part I*, 1 J. ENVTL. FORENSICS 157-173 (2000); Robert D. Morrison, *Forensic Techniques for Establishing the Origin and Timing of a Contaminant Release, in* EXPERT WITNESSING: EXPLAINING AND UNDERSTANDING SCIENCE 145 (Carl Meyer ed., 1999).

43. *See* Kim Hollaender & Michelle Ann Kaminsky, *The Past, Present and Future of Envtl. Insurance Including a Case Study of MTBE Litigation*, 1 J. ENVTL. FORENSICS 205, 208 (2000) (discussing how the "trigger" is applied). *See also* Brian L. Murphy & Phillip N. Sanborn, *Technical Issues in Superfund Insurance Litigation*, 5 ENVTL. CLAIMS J. 573, 587 (1993).

A large number of environmental forensic investigations involve multicomponent distribution analysis of complex mixtures, particularly for petroleum hydrocarbons,[44] polychlorinated biphenyls ("PCBs"),[45] and polychlorinated dibenzo dioxins and furans (PCDD/Fs).[46] Distribution analysis often results in diagnostic fingerprint patterns, which are beneficial for pinpointing the source of the contaminant. Each of the mixtures, petroleum hydrocarbons, PCBs and PCDD/Fs, can present both the analytical chemist and forensic investigator with difficulties.[47] For petroleum hydrocarbons and PCBs, data interpretation is complicated by variations in the content of the original formulation, while for PCDD/Fs, variability in the composition of combusted materials and combustion conditions present similar complications. For all of these mixtures,

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44. The chemistry of petroleum byproducts has been discussed in various texts. *See, e.g.*, James Speight, THE CHEMISTRY AND TECHNOLOGY OF PETROLEUM, (Marcel Dekker 3rd ed., 1999). *See also* Isaac R. Kaplan et al., *Forensic Envtl. Geochemistry: Differentiation of Fuel-Types, Their Sources and Release Times*, 27 ORG. GEOCHEM. 289 (1997) (summarizing many analytical chemistry techniques useful to forensically characterize petroleum hydrocarbons).

45. M.D. Erickson, ANALYTICAL CHEMISTRY OF PCBS, (2nd ed., 1997). From 1929 to 1979, PCBs had numerous industrial uses, including hydraulic fluids, solvents, plasticizers, printing inks, paints and dielectric fluids in capacitors and transformers and their commercial utility was largely based on their chemical stability. *Id.* at 35, 37.

46. *See* C. Rappe, *Dioxins, Patterns and Source Identifications*, 348 FRESENIUS J. ANAL. CHEM. 63, 68 (1994). Polychlorinated dibenzo-p-dioxins ("PCDDs") and dibenzofurans ("PCDFs") are chlorinated tricyclic planar aromatic compounds, with 75 PCDD and 135 PCDF isomers (congeners) possible. *Id.* at 68. PCDD/Fs are not industrial products, but are released into the environment in trace concentrations *via* various combustion processes. *Id. See also* R.E. Alcock and K.C. Jones, *Dioxins in the Environment: A Review of Trend Data,* 30 ENVTL. SCI TECH. 3133 (1996). PCDD/Fs are also formed as unwanted byproducts from various chlorinated formulations. *Id.* at 3133.

47. *See* Wait, *supra* note 14, at 42-43 (describing some of the difficulties in identifying the sources of PCBs and PCDD/Fs).

once they are in the environment, further complications arise from preferential degradation of select constituents within each mixture by weathering effects.[48] Successful forensic studies of mixtures require reliable qualitative and quantitative data. In addition, multivariate statistical techniques, such as Principal Component Analysis ("PCA") and Polytopic Vector Analysis ("PVA"), may aid the forensic investigator in evaluating and demonstrating unique attributes of a set of data.[49]

Understanding different techniques used in forensic analysis of complex mixtures may be beneficial to the reader in order to appreciate these tools. In one example, researchers attempted to differentiate sources of PCDD/Fs in Newark Bay Estuary sediments using historical information, radioisotope dating, sophisticated gas chromatography/mass spectroscopy ("GC/MS") analyses, and PVA data analysis.[50] Within the study area, the researchers found three source-specific PCDD/F fingerprint patterns consistent with combustion sources, sewage sludge, and PCB formulation byproducts.[51] In another example, investigators used PCB congener patterns of a known point source to evaluate sources of PCB contamination in a variety of fish collected from the St. Lawrence River.[52] Regarding petroleum hydrocarbon contamination, forensic

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48. Weathering is the chemical, physical, and biological alteration of substances in the environment. Wait, *supra* note 14, at 42 (explaining that weathering can make it more difficult to identify PCB fingerprint patterns).

49. *See, e.g.*, Allen D. Uhler et al., *A Picture is Worth a Thousand Words*, SOIL & GROUNDWATER CLEANUP 41 (Nov. 1998). For a more detailed discussion see Brian Rohrback, *Software Approaches to Hydrocarbon Pattern Recognition, in* UNIVERSITY OF WISCONSIN-MADISON: HYDROCARBON PATTERN RECOGNITION AND DATING § 4A (Nov. 1997).

50. *See* S.L. Huntley et al., *Identification of Historical PCDD/F Sources in Newark Bay Estuary Subsurface Sediments Using Polytopic Vector Analysis and Radioisotope Dating Techniques*, 36 CHEMOSPHERE 1167, 1170, 1172 (1998).

51. *Id.* at 1167.

52. *See* Syni-An Hwang et al., *Fingerprinting Sources of Contamination: Statistical Techniques for Identifying Point Sources of PCBs*, 2 J. OCCUP. MED. TOXICOL. 365, 367 (1993). *See*

researchers used pattern recognition and source-specific diagnostic ratios to allocate the sources of polynuclear aromatic hydrocarbons ("PAHs") in sediments of the Prince William Sound, Alaska following the *Exxon Valdez* oil spill.[53] This study successfully discriminated among biological PAHs, combustion product (pyrogenic) PAHs, natural petrogenic background PAHs from seeps, and petroleum PAHs associated with tanker spills.[54]

The aforementioned studies were supposedly based on data of known and sufficient quality and integrity. Anything less would undermine the conclusions reached by the forensic researchers and the defensibility of the results if scrutinized by adversarial parties.

II. DATA QUALITY

The quality of data underpins the value and validity of decisions arrived at by environmental managers and litigators. The concepts and importance of quality control ("QC") and quality assurance ("QA") in analytical chemistry have been recognized for many decades.[55] It was not until regulatory methods were established, however, that formal quality control procedures became a mandatory element of environmental investigations. In the late 1970s, the EPA formally recognized the importance of quality assurance programs and quality control procedures at the analytical[56]

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generally id. (providing a detailed description of the test and its techniques).

53. *See generally* David S. Page et al., *Identification of Hydrocarbon Sources in the Bethnic Sediments of Prince William Sound and the Gulf of Alaska Following the* Exxon Valdez *Oil Spill, in* EXXON VALDEZ OIL SPILL: FATE AND EFFECTS IN ALASKAN WATER 41 (ASTM Special Technical Publication No. 1219, 1995) (describing the methods used to identify contamination sources).

54. *Id.* at 61-69 (discussing the study's results).

55. *See, e.g.*, G. Ludnell, *The Chemical Analysis of Things as They Are*, 5 INDUSTRIAL AND ENGINEERING CHEMISTRY, ANALYTICAL ED. (Howe ed. 1933) (*reprinted in* ANALYTICAL CHEMISTRY: KEY TO PROGRESS ON NATIONAL PROBLEMS (Meinke & Taylor eds. 1972).

56. *See generally* U.S. ENVTL. PROTECTION AGENCY, HANDBOOK FOR ANALYTICAL QUALITY CONTROL IN WATER AND WASTEWATER LABORATORIES (1979).

and project levels.[57] Coinciding with regulatory promulgation of quality control programs, professional organizations such as the American Society of Testing and Materials ("ASTM") and the Association of Official Analytical Chemists were also proposing QA guidelines. For example, in 1978 the American Chemical Society convened a group of respected analytical chemists to establish guidelines for data acquisition and data quality evaluation in environmental chemistry.[58] At the same time, the ASTM issued a guidance, which detailed criteria for collection of forensic data.[59] In 1996, Congress mandated that Federal agencies shall consult with the private sector and consensus standard groups, such as ASTM, in developing technical standards.[60] For example, the EPA has just approved the use of non-EPA test methods produced by private professional organizations for the analysis of drinking water regulated under the Clean Water Act.[61] The importance of data

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57. *See generally* U.S. ENVTL. PROTECTION AGENCY, INTERIM GUIDELINES AND SPECIFICATIONS FOR PREPARING QUALITY ASSURANCE PROJECT PLANS (1980).

58. *See* American Chemical Society, *Guidelines for Data Acquisition and Data Quality Evaluation in Envtl. Chemistry*, 52 ANAL. CHEM. 2242, 2242 (1980) (stating that the practices used were varied so results differed as well). More recently, a national consensus standard was authorized by the American National Standards Institute and developed by the American Society of Quality Control. *See also generally* AM. NAT'L STANDARD, SPECIFICATIONS AND GUIDELINES FOR QUALITY SYSTEMS FOR ENVTL. DATA COLLECTION AND ENVTL. TECH. PROGRAMS (1995).

59. ASTM Committee E-30 on Forensic Sciences published numerous standards at that time, including STANDARD PRACTICE FOR REPORTING OPINIONS OF TECHNICAL EXPECTS (1977); STANDARD PRACTICE FOR EVALUATION OF TECHNICAL DATA (1980); STANDARD PRACTICE FOR EXAMINING AND TESTING ITEMS THAT ARE OR MAY BECOME INVOLVED WITH LITIGATION (1982).

60. H.R. Con. Res. 2196 §12(d)(2), 104th Cong. (1996) (adding 15 U.S.C. § 272(b) (13), the Nat'l Institute of Standards and Technology Act) (enacted).

61. *See, e.g.*, 40 C.F.R. pts. 136, 141, and 143, Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act, 66 FED. REG. 3466-02; 40 CFR pts. 136, 141, and 143 Guidelines Establishing Test Procedures for the Analysis

quality was highlighted in a law enacted in December 2000 by the 106th Congress.[62] The law mandates that by September 30, 2001, the Office of Management and Budget must issue guidance to agencies for "ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by federal agencies."[63]

As an extreme example of the importance of data quality, U.S. researchers have recently suggested that when conducting site assessments for certain organic anthropogenic chemicals where chiral forms of the chemical structure exist,[64] the more toxic enantiomer structure was not analyzed for.[65] As such, the quality and usability of a large amount of environmental data collected worldwide may be questionable for the purposes of conducting risk assessments.[66]

The level of data quality can vary to some extent depending on the objectives of the study, but its integrity cannot. "Data quality objectives ("DQO") are statements of the level of uncertainty that a decision-maker is willing to accept."[67] Procedures for developing DQOs have been established by both EPA[68] and ASTM.[69] DQOs are

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of Pollutants Under the Clean Water Act, 66 FED. REG. 3526 (January 16, 2001).

62. H.R. Con. Res. 4577 § 515 (a), 106th Cong. (2000).

63. *Id. See also* Cheryl Hogue, *Federal Data Soon Must Meet Quality Standards*, 79 CHEMICAL ENGINEERING NEWS 7 (2001) (reporting the institution of the new law, PL 106-554, and describing how it should work).

64. *See* David L. Lewis et al., *Influence of Envtl. Changes on Degradation of Chiral Pollutants in Soils* 401 NATURE 898, 898 (1999). Some examples of chiral compounds (three-dimensional molecules that cannot be superimposed on their mirror image) include phenoxy acid herbicides, organophosphorus insecticides, PCBs, phthalates, freon substitutes, and some DDT derivatives. *Id.*

65. *Id.*

66. *Id.* at 901.

67. Maney & Wait, *supra* note 2, at 21.

68. *See generally* U.S. ENVTL. PROTECTION AGENCY, GUIDANCE FOR THE DATA QUALITY OBJECTIVES PROCESS (2000).

69. *See generally* ASTM, STANDARD PRACTICE FOR GENERATION OF ENVTL. DATA RELATED TO WASTE MANAGEMENT ACTIVITIES: DEVELOPMENT OF DATA QUALITY OBJECTIVES (1996).

often confused with acceptable levels of analytical accuracy and precision. However, analytical uncertainty is only a portion of the uncertainty of an environmental measurement and only one element of an environmental decision. DQOs should also consider the uncertainty in health-based standards, exposure pathways, and sample collection, since they all contribute to the overall uncertainty of a decision.[70] Uncertainty can be difficult to measure.[71]

Confounding the situation is the variability and "failure to consider variability in assessing data collected for regulatory purposes [which] can lead to 'false' liability or excessive regulatory burdens."[72] For example, in *Amoco Oil Co. v. Environmental Protection Agency*,[73] the court heard arguments about the adequacy of test methods for determining lead content in gasoline.[74] The court opened:

> [T]he possibility of statistical measurement error, which is often unavoidable where regulations set quantitative standards, does not detract from an agency's power to set such standards. It merely deprives the agency of the power to find a *violation* of the standards, in enforcement proceedings, where the measured departure from them is within the boundaries of probable measurement error.[75]

As such, any exceedance of a regulatory standard, even though that exceedance falls within the variability of the method,

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70. Maney & Wait, *supra* note 2, at 21.

71. *See e.g.*, T. Georgian, *Estimation of Laboratory Analytical Uncertainty Using Laboratory Control Samples*, 9 ENVTL. TEST. & ANAL. 20, 20 (2000) (describing the difficulty of determining the analytical uncertainty of a measurement).

72. Steven J. Koorse, *False Positives, Detection Limits and Other Laboratory Imperfections: The Regulatory Implications* 19 ENVTL. LAW REPORTER 10211, 10211 (1989). *See also generally* Libby Ford et al., *Envtl: Russian Roulette – Compliance at or Near the Detection Level*, 2 WATER ENV'T & TECH. 58 (1990) (describing the problems presented by lack of consistent cleanup standards).

73. 501 F. 2d 722 (D.C. Cir. 1974).

74. *Id.* at 741-743 (rejecting the argument that using a lead content ceiling was arbitrary and capricious).

75. *Id.* at 743.

constitutes an enforceable violation. Exceeding regulatory requirements for pollutant discharge can be extremely expensive for the discharger.[76]

Evaluation of a measurement process requires numerous levels of detail to be addressed.[77] Measurable factors are those factors whose impact on the accuracy,[78] precision,[79] and representativeness[80] of a measurement process that can be detected, monitored, and quantified by quality control samples. The proper

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76. *See* Zygmunt J.B. Platter et al., ENVTL. LAW AND POLICY: NATURE, LAW, AND SOCIETY 61 (2nd ed. 1998). The extent of financial penalty a discharger may have to pay for exceeding wastewater permit limits is exemplified in *Chesapeake Bay Foundation v. Gwaltney of Smithfield, Ltd.*, 611 F. Supp. 1542 (1984), where penalties nearing $1.3 million were assessed. *Id.* at 66.

77. Maney & Wait, *supra* note 2, at 20.

78. *See* ASTM, STANDARD PRACTICE FOR GENERATION OF ENVTL. DATA RELATED TO WASTE MANAGEMENT ACTIVITIES: DEVELOPMENT OF DATA QUALITY OBJECTIVES (1996) [hereinafter ASTM, STANDARD PRACTICE FOR GENERATION OF ENVTL. DATA]. Accuracy is defined as the closeness of a measured value to the true value or the closeness of a measured value to an accepted reference or standard value. *Id.* at 487. Bias, often confused with accuracy, is the difference between the population mean of the test results and an accepted reference value. *Id.*

79. Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act, 66 FED. REG. 3466-02; 40 CFR Parts 136, 141, and 143 Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act, 66 FED. REG. 3526 (Jan. 16, 2001). Precision is defined as the generic concept used to describe the dispersion of a set of measured values.

80. *See* ASTM, STANDARD GUIDE FOR REPRESENTATIVE SAMPLING FOR MANAGEMENT OF WASTE AND CONTAMINATED MEDIA (1997). Representativeness of a sample is defined as a sample collected in such a manner that it reflects one or more characteristics of interest (as defined by the project objectives) of a population for which it is collected, although the samples individually may not be representative. *Id.* at 505.

identification of an analyte being quantitated is also essential,[81] and it should not be assumed.[82] Information derived from quality control samples is summarized in Table 1. Measurable factors include blanks, which provide information on possible contamination during sampling and analysis activities;[83] replicates, which provide information on precision; and spikes, which indicate bias. Another important measurable factor is sensitivity, which is the limit of detection of an analytical method.

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81. *See* Kathleen C. Swallow et al., *Hazardous Organic Compound Analysis*, 22 ENVTL. SCI. TECH. 136, 136 (1988) (stating that accurate identification is critical in determining leakage sites). Proper identification of compounds found in environmental samples would enhance the reliability of identification. *Id.* at 141.

82. A study commissioned by EPA and performed by the Advancement of Sound Science Coalition found that 11% of 2000 studies evaluated had "serious deficiencies" with pesticide testing results. *See* Carl Meyer, *Distinguishing Good Science, Bad Science and Junk Science*, *in* EXPERT WITNESSING: EXPLAINING AND UNDERSTANDING SCIENCE 99, 116 (Carl Meyer ed., 1999).

83. *See* John P. Maney, *Assessing Blank Data* 6 ENVTL TEST. AND ANAL. 20, 20 (1997) (stating that blanks are employed to detect contamination).

Table 1: Information Derived from Quality Control Samples[84]

	Type of Information											
	Contamination					Precision			Bias			
QC Sample Type	Containers	Field Environment	Equipment	Cross Contamination	Laboratory	Sampling	Splitting	Preparation & Analysis	Spiking	Field/Ship/Storage	Laboratory
Blanks											
Trip	X			X	X						
Field	X	X		X	X						
Equipment	X	X	X	X	X						
Method					X						
Replicates											
Splits (Field)							X	X			
Collocated (Field)						X		X			
Splits (Lab)							X	X			
Spikes											
Field									X	X	X
Matrix (Lab)									X		X
Blank (Lab)									X		X

Although a theoretical analytical chemist may view this strictly as the "signal to noise" ratio of an instrument, more practically a detection limit must reflect the vagaries of method performance as well as the influence of a sample matrix. EPA has defined a method detection limit as "the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the true value is greater than zero."[85] EPA has further defined a Practical Quantitation Limit as "the lowest level that can be reliably achieved within specified limits of precision and

84. Maney & Wait, *supra* note 2, at 23. This table is based on definitions in ASTM STANDARD D-5792-95, STANDARD PRACTICE FOR GENERATION OF ENVTL. DATA RELATED TO WASTE MANAGEMENT ACTIVITIES: QUALITY ASSESSMENT/QUALITY CONTROL PLANNING AND IMPLEMENTATION (1996).

85. Guidelines Establishing Test Procedures for the Analysis of Pollutants; Measurement of Mercury in Water (EPA Method 1631, Revision B); Final Rule, 40 CFR pt. 136 (June 8, 1999).

accuracy during routine laboratory operating conditions."[86] Commercial laboratories use various means and terms to report detection limits to a client.[87] Understanding to what level a laboratory is reporting a nondetect is crucial to a forensic investigator, and if not properly delineated can lead to inappropriate use of a method or a misunderstanding as to whether an analyte is present.[88] It behooves a forensic investigator to ensure that the test method of choice actually achieves the detection limit required for the study.

Nonmeasurable factors are those whose impact cannot be detected by quality control samples, but can be controlled through QA programs, standard operating procedures (SOPs), documentation procedures, and training. Over the past few years, EPA's Quality Assurance Division has been developing a comprehensive set of quality system guidance documents to be used when conducting sampling and analysis programs.[89] Unlike measurable factors that can be detected by QC samples, a nonquantitative and somewhat subjective evaluation by an experienced forensic chemist is

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86. National Primary Drinking Water Regulations; Volatile Synthetic Organic Chemicals, 50 FED. REG. 46902, 46906-46908 (Nov. 13, 1985) (to be codified at 40 C.F.R. pts. 141 & 142).

87. *See generally* Ann Rosecrance, *The Three "Rs" for Relevant Detection, Reliable Quantitation and Respectable Reporting Limits*, 9 ENVTL. TEST. AND ANAL. 13 (2000) (providing a summary of the more common terms and meanings of reporting limits used by commercial laboratories).

88. *See* Koorse, *supra* note 72, at 10214 (describing that when analytical variability is not adequately considered, regulations that are based on that analysis may have "harsh economic ramifications."). *See also* Diane Lambert et al., *Nondetects, Detection Limits, and the Probability of Detection,* 86 J. AMER. STAT. ASSOC. 266, 266 (1991).

89. *See* U.S.ENVTL. PROTECTION AGENCY, THE EPA QUALITY SYSTEM (1998), *available at* http://www.epa.gov/quality/qa_docs.html. Regarding EPA's quality systems cited herein, EPA Region IX states: "As all EPA decisions ultimately involve data collection, these documents are the heart of the EPA data collection system." *Final Requirements on Data Quality to be Issued Soon, EPA Official Says*, 29 ENVTL. REPORTER 516 (1998).

necessary to determine if nonmeasurable factors have affected the accuracy and representativeness of a measurement.[90]

When the forensic chemist is confronted with using a nonstandard method, it is often prudent to modify a proven or standard method rather than to start anew.[91] "Novel methods are often fraught with unforeseen problems that are not amenable to problem-solving research within the time framework and budget of an environmental [forensic] study."[92] When constructing a method, the proposed protocol must first be optimized and tested for ruggedness.[93] The resultant method's performance must then be shown to be adequate for matrices and analytes of interest via method detection limit studies.[94] Once the method has been shown capable of meeting all analytical data quality objectives, a QA/QC system must be instituted that will define, demonstrate and document method performance.[95] Accuracy, precision, representativeness, and sensitivity are parameters which should be measured in evaluating the quality of data. The manner in which these parameters are measured and evaluated for nonstandard methods may vary from standard methods. However, it is usually advisable to start with measures and acceptance criteria of similar standard methods and

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90. *See* Wait, *supra* note 2, at 22-23.

91. A. Dallas Wait & Gregory S. Douglas, *QA for Nonstandard Analytical Methods*, 7 ENVTL. LAB. 30 (1995).

92. *Id.* at 30-31.

93. *See* American Society for Testing and Materials (ASTM), *Standard Guide for Conducting Ruggedness Testing*, Method E1169-89 (1989). Ruggedness tests "find the variables (experimental factors) that strongly influence the measurements provided by the test method and determine how closely the variables need to be controlled." *Id.* at 674. Method detection limit is "defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analytes." *Id.*

94. National Primary Drinking Water Regulations; Volatile Synthetic Organic Chemicals, 50 FED. REG. 46902, 46906 (Nov. 13, 1985) (to be codified at 40 C.F.R. pts. 141 & 142); 40 C.F.R. Part 136 App. B. (1987).

95. *See, e.g., generally* John K. Taylor, QUALITY ASSURANCE OF CHEMICAL MEASUREMENTS (1987).

then revise those criteria, if necessary, during the method optimization process.[96]

Practitioners of regulated analytical methods may face the same QA/QC conundrum that the forensic chemist faces using nonstandard methods. There have been recent attempts within many of the EPA's offices to adopt performance-based measurement systems ("PBMS").[97] PBMS will allow a commercial laboratory to adopt a certain level of flexibility in the methods it institutes, so long as quantifiable QA goals are met.[98] Concern has been raised by many investigators regarding the legal uncertainties and lack of case law for PBMS,[99] including potential liabilities for the laboratory, and comparability of historical data with new results.[100] As with environmental forensics, for PBMS to be successful, it is critical that experienced senior level chemists be involved with developing clear

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96. *See* Wait & Douglas, *supra* note 91, at 30.

97. *See* Jon S. Kauffman & Don Wyand, *Successful Application of the PBMS Approach*, 9 ENVTL. TEST AND ANAL. 15, 16 (2000) (reporting that two EPA offices, the Office of Solid Waste and the Office of Water, have began using the PBMS approach).

98. *Id.* at 15.

99. *See, e.g.*, Public Interest Research Group of New Jersey, Inc. v. Elf Autochem North America, *Inc.* 817 F. Supp 1164, 1181 (D.N.J. 1993) (finding the use of unapproved methods for testing unacceptable).

100. *See generally* Paul Mills, *PBMS: Status, Projections, and Conjectures,* 7 ENVTL. TEST. AND ANAL. 20, 22 (1998) (stating the importance of PBMS audits to ensure its proper use and accurate results); Paul Mills, *Auditing PBMS: What to Expect,* 8 ENVTL. TEST. AND ANAL. 40 (1999) (describing some of the risks associated with PBMS); Richard G. Mealy, *Data Comparability and Defensibility,* 2 ENVTL. TEST. AND ANAL. 36 (1993) (describing the consequences of method modification). *See also, e.g.*, Jonathan B. Butcher, et al., *Use of Historical PCB Aroclor Measurements: Hudson River Fish Data,* 16 ENV'T TOX. AND CHEM. 1618 (1997) (reporting data comparability when researchers evaluating nearly two decades of PCB data from fish collected in the Hudson River were confounded in their assessment of the data due to different GC methods that were used over that time period).

data quality objectives prior to initiating investigation,[101] documenting the plan,[102] overseeing the implementation of methods, and evaluating the integrity and usability of the results.[103]

III. DATA INTEGRITY

Analytical chemistry results should be what they purport to be. Investigators and litigators often rely on data, which they assume to be truthful and representative of the testing performed but they should assume nothing.[104] All aspects of sample collection, sample analysis, and data generation should be recreated and verified prior to litigation. The critical importance of producing data of known quality and integrity was highlighted in the national press a few years ago. In 1997, the Inspector General issued a scathing report of the Federal Bureau of Investigation's shoddy forensic analytical chemistry and document control practices in its crime lab while evaluating evidence in the Oklahoma City bombing

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101. *See, e.g.,* A. Dallas Wait & Linda L. Cook, *Opportunities in Envtl. Forensic Chemistry Analysis,* 8 ENVTL. TEST. AND ANAL. 31, 32 (1999) (describing the importance of hiring a senior level forensic chemistry expert).

102. *See, e.g.,* Barry Lesnik & Deana Crumbling, *Guidelines for Preparing SAPs: Using Systematic Planning and PBMS,* 10 ENVT'L TESTING AND ANAL. 26, 28, 30 (suggesting that documents may include quality assurance project plans ("QAPP") and standard operating procedures ("SOPs")).

103. *See generally* ASTM, STANDARD PRACTICE FOR GENERATION OF ENVTL. DATA, *supra* note 78. *See also generally* NATIONAL ENVTL. LABORATORY ACCREDITATION CONFERENCE (NELAC), EMMC WORKGROUP, PERFORMANCE-BASED MEASUREMENT SYSTEM, Ch. 5 (July 1, 1999), *available at* http://www.epa.gov/ttnnela1.htm (setting forth the standards established and providing checklists to be used by laboratories using PBMS).

104. *See* Mark W. Roberts, *Environmental Forensics Are An Essential Element Of Every Investigation,* 17TH ANNUAL INTERNATIONAL CONFERENCE OF CONTAMINATED SOILS, SEDIMENTS AND WATER, at 79 (2000) (describing the importance of uncovering all relevant information and assuming nothing during an investigation).

investigation.[105] The botched forensics work performed in the O.J. Simpson trial is another glaring example of poor data integrity.[106]

The proper use of QA and QC protocols, the implementation of a thorough document control system, the use of comprehensive chain-of-custody procedures, and the conducting of good automated laboratory practices all contribute to the minimizing of faulty and deceptive data reporting.[107] After laboratory results are produced, independent data validation may verify the data reported, and possibly provide clues as to whether fraud has occurred.[108] Consultants to forensic investigators often recommend a more proactive approach to warning laboratories that poor laboratory practices and fraudulent activities will not be tolerated.[109] These

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105. *See* Lois R. Ember, *Report Jolts FBI Lab into Reform*, 75 CHEM. & ENGIN. NEWS 25, 25, 27 (June 16, 1997) (reporting that federal prosecutors found, among other things, inaccurate tests, insufficient documentation of test results and scientifically flawed reports). Results of the U.S. Department of Justice's investigation into this matter have been published in U.S. DEP'T OF JUST., THE FBI ONE YEAR LATER: A FOLLOW-UP TO THE INSPECTOR GENERAL'S APRIL 1997 REPORT ON THE FBI. PRACTICES AND ALLEGED MISCONDUCT IN EXPLOSIVE RELATED AND OTHER CASES (June 1998), *available at* http://www.usdoj.gov/oig/fbi1yr.htm.

106. *See* Robert Stevenson, *Crisis in Forensic Science: Fallout in the Courts and Society* 30 AMER. LAB. 4, 4 (1998) (stating that after the O.J. Simpson trial, forensic scientists are looking 'bad' and forensic science has become sloppy).

107. *See, e.g.*, Jeffrey C. Worthington & R. Park Haney, *Data Authenticity and Data Integrity: Essential Concerns for the Envtl. Laboratory*, AMER. ENVTL. LAB. 15, 17-18 (Dec. 1991) (suggesting that, for example, internal audits, reviews of liability procedures and membership in a laboratory accreditation program, will help ensure data authenticity).

108. *See, e.g., generally* Thomas Georgian, *Validation of Performance-Based Chemical Data* in EPA 17TH ANNUAL NAT'L CONF. ON MANAGING ENVTL. QUALITY SYSTEMS: CREATING NEW TOOLS FOR EMERGING ENVTL. ISSUES (April 1998) (discussing the importance of data validation).

109. *See* Maney & Wait, *supra* note 2, at 23 (stating that data quality forces upfront consideration of details in order to offer the greatest potential for data with integrity).

approaches may include, in part, preprogram lab audits and unannounced visits during the program,[110] mandatory participation in accreditation and certification programs,[111] submission of overt and blind performance evaluation samples, and more sophisticated third-party computer analysis of raw data.[112] Yet with all these safeguards, deceptive data manipulation still remains a problem.

The reasons for fraud are varied, but often are related to the laboratory's financial pressures.[113] Other reasons for fraud include fines that are imposed based upon contractual report due dates, sample analysis hold time requirements,[114] poor communication, inadequate training of staff, and questionable management ethics.[115] The resulting types of fraudulent activities often include bench sheet

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110. *See generally* Nile A. Luedtke, *Integrity and Auditing* 2 ENVTL. TEST. AND ANAL. 56 (1993) (describing the types of audits that should be conducted and how to conduct them). *See also* Jeffrey C. Worthington & Kerri G. Luka, *Evidence, Audits and Data Defensibility* 3 ENVTL. LAB. 52, 52 (1991) (discussing the importance of audits in identifying potential problems in court, such as chain of custody).

111. *See* Russ Gager, *Accreditation Efforts, Fraud Charges Still Dominate Envtl. Lab Arena.* HAZMAT WORLD 65, 65 (May 1991) (stating that accreditation and certification programs on a nationwide level is being considered).

112. *See generally* Andrew Sauter & A. Dallas Wait, *Perspectives on Data Integrity and Quality* 4 ENVTL. LAB. 25 (1992) (regarding third party computer analysis of raw data). *See also generally* Michael J. Wilson, *QA and Magnetic Tape Audits*, 4 ENVTL. TEST. AND ANAL. 56 (1995) (describing the importance of computers for several methods of contamination determination).

113. *See Labs Face Ongoing Survival Test,* 7 ENVTL. BUS. J., Oct. 1994, at 1. *See also Bankruptcies Plague Envtl. Laboratory Sector,* GOLOB'S ENVTL. BUS. WEEK 1-2 (Mar. 27,1998). A commercial environmental laboratory business is difficult to maintain, often resulting in weak or nonexistent profits. *Id.*

114. Missed holding times may result in rejected data, which, in turn, may mean the laboratory is not paid.

115. *See* John R. Troost, *CLP Fraud: Why Chemists Cheat*, 6 ENVTL. LAB. 20 (1994) (stating that the unethical behavior is prompted by "resentment and lack of respect for what was viewed as overly stringent, excessive specification of the [CLP] method.").

modifications, alteration of instrument response to an analyte,[116] selective exclusion of data, and actual fabrication of data.[117] Obviously courts should forbid an expert from offering opinions based on a "fictitious set of facts."[118] Detection of fraudulent data and prosecution of perpetrators has become commonplace, to the point that the environmental laboratory industry and its trade associations[119] are vigorously promoting dialogue and guidance to internally rectify the situation.[120] For example, the National Environmental Laboratory Accreditation Conference ("NELAC") requires that environmental laboratories seeking NELAC accreditation:[121]

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116. For example, "peak shaving," which is misrepresented CLP protocol calibration information. *Id.* at 20.

117. *See generally* Joseph F. Solsky, *Questionable Practices in the Organic Laboratory: Part II, in* PROCEEDINGS OF THE FIFTEENTH ANNUAL WASTE TESTING & QUALITY ASSURANCE SYMPOSIUM 121 (July 1999) (describing some questionable practices of today's fraudulent activities including peak-shaving, peak-enhancement and time-travel).

118. *See* Guillory v. Domtar Industries Inc., 95 F. 3d 1320, 1331 (5th Cir. 1996) (stating that relying on fictitious facts is "just as reliable as evidence based upon no research at all.").

119. Two trade associations are the International Association of Envtl. Testing Laboratories ("IAETL") and the American Council of Independent Laboratories ("ACIL"). *See* ACIL's website for facts about ACIL, *available at* http://www.acil.org/about.htm.

120. *See* John J. Pavlick & Jack Farrell, *Preventing Data Fraud* 6 ENVTL. TEST AND ANAL. 15 (1997) (mentioning the leaders of IAETL and ACIL reinforce the importance of data integrity). A successful program results in all members of a firm being aware of potential problems and problems that are discovered. *Id.* at 38. *See also* Rick Schrynemeeckers, *An Integrity Management Program to Eliminate Data Fraud,* ENVTL. TEST AND ANAL. 14 (1999); Deborah A. Loring & Bonnie Smoren, *Where Do Company Ethics Programs Fall Short?,* 9 ENVTL. TESTING AND ANALYSIS 18 (2000).

121. *See* NELAC EMMC WORKGROUP, PERFORMANCE-BASED MEASUREMENT SYSTEM (July 1, 1999), *available at* http://www.epa.gov/ttnela1.htm.

- conduct "training courses in ethical and legal responsibilities, including the potential punishments and penalties for improper, unethical, or illegal actions,"[122]
- maintain "evidence . . . that each employee has . . . understood their personal ethical and legal responsibilities including the potential punishments and penalties for improper, unethical, or illegal actions,"[123] and
- develop "a proactive program for prevention and detection of improper, unethical, or illegal actions," which may include "electronic data and tape audits; [an] effective reward program to improve employee vigilance and co-monitoring; and separate [standard operating procedures] identifying appropriate and inappropriate laboratory and instrument manipulation practices."[124]

There have been so many accounts of environmental data fraud that it is difficult to select any one incident as representative.[125] One example which received a lot of press involved *United States v. Hess Environmental Laboratories*,[126] where a Pennsylvania environmental laboratory admitted defrauding hundreds of clients who were billed over $2.1 million for tests, which were falsified or never performed.[127] The laboratory paid over $5.5 million in fines as

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122. NELAC, QUALITY SYSTEMS 9 (July 1, 1999), *available at* http://www.epa.gov/ttn/nelac/arcstand/5qs_12-0.pdf

123. *Id.*

124. *Id.* at 12.

125. The pervasiveness of the problem extends well beyond just environmental laboratories. *See, e.g., generally* Martin F. Shapiro & Robert P. Charrow, *The Role of Data Audits in Detecting Scientific Misconduct: Results of the FDA Program,* 261 J. AMER. MED. ASSOC. 2505 (1989) (showing, with statistics, the scientific misconduct of researchers involved with U.S. Food and Drug Administration ("FDA") programs during the 1980s).

126. *See generally United States v. Hess Environmental Laboratories et al., No. 97-531 (E.D.Pa., Oct. 21, 1998),*13 No. 11 NAAG Nat'l Envtl. Enforcement J. 39 (Dec. 1998/Jan. 1999) (providing the citation for this unpublished decision as No.97-531 (E.D. Pa. 1997)), *available at* Westlaw 13 No. 11 NAAGNEEJ 39.

127. *Id.*

part of its guilty plea for defrauding customers and violating the Clean Water Act.[128]

Prison sentences and other sentences, besides fines, have also been levied on laboratory directors involved with data falsification. For example, the U.S. District Court in Philadelphia sentenced the laboratory director of Hydro-Analysis Associates, Inc. to serve eighteen months in prison and three years on probation for fraudulently certifying that EPA-certified methods were used to test wastewater, drinking water, soil, and the contents of underground storage tanks.[129] In the case *United States v. Alan Stevens*,[130] Alan Stevens was required, in part, to write a letter to all of his former defrauded customers describing his despicable behavior in falsifying data reports.[131]

The onus for producing reliable analytical data rests with the regulated community. For example, in the Clean Water Act amendment to the Federal Water Pollution Control Act,[132] the permittee, upon signing the Discharge Monitoring Report, endorses that the quality of the data provided and the sampling and analytical procedures used to generate the data were in accordance with the requirements set forth in 40 CFR Part 136.[133] USEPA addresses problems associated with analysis of parameters for the National Pollutant Discharge Elimination System ("NPDES") permitting by requiring case histories where lack of documentation resulted in the rejection of data.[134] The Resource Conservation and Recovery Act of

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128. *See generally* Neil Strassman, *Environmental Tests Falsified, Indictment Says,* THE FORT WORTH STAR-TELEGRAM, Sept. 22, 2000, at 1, *available at* Westlaw, 9/22/00 FTWTHST 1 (reporting cases where falsified laboratory test results caused lawsuits).

129. *See* Golob's ENVTL. BUSINESS REPORT, EBR HOTLINE, Dec. 1, 2000, at 7.

130. Crim. No. 92-10095-JLT (D. Mass. 1996).

131. A copy of the letter is on file with the author and the Fordham Environmental Law Journal.

132. An act to amend the Federal Water Pollution Control Act, Pub. L. No. 92-500, 86 Stat. 816 (codified as 33 U.S.C. § 1251 *et seq.* (1994 & Supp. V. 1999)).

133. *Id.* at 880.

134. *See generally* U.S.ENVTL. PROTECTION AGENCY, GUIDANCE ON EVALUATION, RESOLUTION AND DOCUMENTATION OF

1976 ("RCRA")[135] also stress the importance of methodology adherence and completeness of the evidence file. RCRA clearly defines the lines of responsibility for compositional data under 40 CFR Parts 265, 264, and 270, whereby the generation of reliable data is the sole responsibility of the owner/operator.[136] Therefore, questionable performance on the part of the commercial laboratory will be viewed questionable performance or the part of the owner/operator. For example, in *Brocklesby v. U.S.*,[137] Jeppesen, a co-defendant, claimed that defective data was obtained from the Federal Aviation Administration ("FAA"), and therefore no liability should be attributed to Jeppesen.[138] However, the court maintained that it was Jeppesen's responsibility to verify FAA's data by following its own Standard Operating Procedures (SOPs), which required Jeppesen to verify the integrity of the data.[139]

Unfortunately, laboratory contractors often naively assume that data produced by environmental laboratories are impeccable. Although there are reasonable steps that the purchaser of laboratory services can implement to minimize the generation of unreliable data, there are no guarantees to data quality and integrity, particularly if laboratories are devious.[140] However, it is awkward

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ANALYTICAL PROBLEMS ASSOCIATED WITH COMPLIANCE MONITORING (1993).

135. 42 U.S.C. § 6901 *et seq.* (1994 & Supp. V. 1999)).

136. *See, generally* 40 C.F.R. pts. 164, 165 (providing standards for the owners and operators of hazardous waste treatment, storage and disposal facilities).

137. 967 F.2d 1288 (9th Cir. 1985).

138. *Id.* at 1295 (stating that Jeppesen argued it shouldn't be strictly liable because it was not at fault).

139. *Id.* at 1296 (finding that Jeppesen had "both the ability to detect an error and a mechanism for seeking corrections).

140. *See* Wallin et al., *supra* note 20, at 38-39 (setting forth steps of risk management: identifying the issues, analyzing the identified risks, assessing, selecting and implementing data quality risk management alternatives and monitoring and making improvements, as necessary). USEPA has provided guidance for detectin and deterring fraud. *See* CALIFORNIA MILITARY ENVIRONMENTAL COORDINATION COMMITTEE, CHEMICAL DATA QUALITY/COST REDUCTION PROCESS ACTION TEAM, REGION 9-BEST PRACTICES FOR THE DETECTION AND DETERRENCE OF LABORATORY

for federal and state agencies to castigate the regulated community for poor quality data when similar problems persist with their own laboratories. For example, USEPA is experiencing many data quality and integrity problems with their own contract laboratories, as well as their own internal laboratories. Some examples follow:

- Of the more than one hundred laboratories which had been contracted in 1991 by the USEPA for Superfund sample analyses under CLP, twenty-two were under investigation by the U.S. Department of Justice for fraudulent activities.[141]
- A 1997 audit conducted by USEPA Office of Inspector General evaluated nine federal Superfund sites in USEPA Regions 8, 9, and 10.[142] The results found that more than 11 million dollars had been wasted on unreliable, and in some cases fraudulent, data.[143] One recommendation in the report was to "[e]stablish procedures for ensuring fraudulent or poor quality data is not used at Federal facility cleanups."[144]
- The U.S. Department of Justice and USEPA have begun investigating possible fraudulent data manipulation activities at USEPA's laboratory in Chicago (USEPA Region 5).[145] Most of the concern focuses on poor instrument calibration practices.[146]

In response to some of these problems, USEPA commissioned a Science Advisory Board review of its Quality

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FRAUD (1997) *available at* http://www.epa.gov/region09/qa/labfraud.html.

141. *See* Pamela S. Zurer, *Contract Labs Charged with Fraud in Analyses of Superfund Samples,* 69 CHEM. & ENGIN. NEWS 14, 14 (Feb. 25, 1991).

142. *See* OFFICE OF INSPECTOR GENERAL, U.S.ENVTL. PROTECTION AGENCY, REPORT OF AUDIT: LABORATORY DATA QUALITY OF FEDERAL FACILITY SUPERFUND SITES iii (Mar. 20, 1997).

143. *Id.*

144. *Id.* at 26.

145. John Fialka, *Justice Department, EPA Probe Cases of Alleged Manipulation of Evidence* WALL ST. J., Mar. 27, 2000, at A50.

146. *Id.* (stating that the data was manipulated to produce a standard linear result).

System. The Science Advisory Board issued a report in 1999 which recognizes that the Agency needs to improve its own data collection activities to ensure data produced is of known quality and is defensible.[147]

IV. DATA ADMISSIBILITY

For evidence to be admissible, it must be "of such a character that the court or judge is bound to receive it; that is, allow it to be introduced at trial."[148] As such, admissible evidence must be relevant and authentic. Guidance and standards for the admissibility of evidence have been debated in the legal community for decades; evolving from common law through various case law and federal law standards.[149] In 1923 the Frye Rule, resulting from *Frye v. United States*, [150] became the first standard applied to the admissibility of scientific data. The Frye Rule provided that the admissibility of expert testimony depended on whether the subject of the testimony was "sufficiently established to have gained general acceptance in the particular field in which it belongs."[151] In 1975, more than fifty years after *Frye*, the Federal Rules of Evidence were codified.[152] Federal Rule 104 concerns questions of admissibility and relevancy, while Federal Rules 403, 702, and 703 relate directly to scientific testimony. The Daubert Rule opined in *Daubert v. Merrill-Dow Pharmaceuticals, Inc.*[153] was the first United States Supreme Court ruling which gave guidance to admissibility of

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147. *See generally* SCIENCE ADVISORY BOARD, U.S.ENVTL. PROTECTION AGENCY, SCIENCE ADVISORY BOARD REVIEW OF THE IMPLEMENTATION OF THE AGENCY-WIDE QUALITY SYSTEM (letter report to Carol M. Browner) (Feb. 25, 1999), *available at* http://www.EPA.gov/SAB/FISCLRPT.htm (detailing the findings of the 1999 report).

148. BLACK'S LAW DICTIONARY 47 (6th ed. 1990).

149. This paper is not meant to examine the arguments and interpretations of these rulings, but only to provide a law context for environmental forensics concerns.

150. 293 F. 1013 (D.C. Cir. 1923).

151. *Id.* at 1014.

152. Pub. L. No. 93-595, 88 Stat. 1926 (establishing the rules of evidence).

153. 509 U.S. 579 (1993).

scientific theory and evidence. More recent rulings have helped to provide clarification on Daubert both from a scientific[154] and non-scientific[155] standpoint, although a certain level of disconnect exists between law and science because of "differing goals, habits of mind, and structures of the two disciplines."[156]

The Daubert ruling anticipates that district courts will have a gatekeeping role with respect to scientific evidence such as is needed in environmental forensics. The Supreme Court noted that to ensure the relevancy and reliability of scientific evidence, FRE Rule 702 should be interpreted in conjunction with Rule 104(a). The resulting Daubert factors include:

(1) Does the theory or technique involve testable hypotheses?[157]
(2) Has the theory or technique been subjected to peer review and publication?[158]
(3) Are there known or potential error rates, and are these standards controlling the technique's operation?[159]
(4) Is the technique generally accepted in the scientific community?[160]

It should be noted that Daubert neither requires nor empowers trial courts to decide which of several competing scientific theories is best.[161]

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154. *See, e.g.*, General Electric v. Joiner, 522 U.S. 136, 146 (1997) (holding that the scope of review for a district court's ruling on the admissibility of scientific evidence is abuse of discretion).

155. *See, e.g.*, Kumho Tire Co. v. Carmichael, 526 U.S. 137, 147 (1998) (applying *Daubert* to all expert testimony, not just scientific testimony).

156. *See* David T. Case & Jeffrey B. Ritter, *Disconnects Between Science and the Law*, 78 CHEM. & ENGIN. NEWS 49 (Feb. 14, 2000).

157. Daubert, 509 U.S. at 593.

158. *Id.*

159. *Id.* at 594.

160. *Id.*

161. *See* Ruiz-Troche v. Pepsi-Cola of Puerto Rico Bottling Co., 161 F. 3d, 77, 81 (1st Cir. 1998) (stating that trial judges may evaluate offered data if it provides support that the expert's testimony is reliable).

Currently a significant number of Daubert challenges relating to the admissibility of scientific opinion involve toxic chemical exposure claims.[162] For example, in *Diane Lofgren v. Motorola*,[163] plaintiffs' medical experts claimed injuries associated with environmental exposure to trichloroethylene ("TCE") in the East Phoenix, Arizona area;[164] but the judge granted summary judgment to the defendants on the grounds of lack of admissible medical causation testimony.[165]

The issue of admissibility of scientific testimony in the court involves the expert,[166] the data, and the evaluation and subsequent opinions engendered from the data.[167] Meyer has presented many issues which determine whether good science is likely to prevail in the court, these being whether:[168]

- "The underlying scientific theory is solid,

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162. *See generally* R. Wade Marionneaux & Voris E. Johnson, Jr., *Differential Diagnosis: The Next Daubert Frontier,* 13 MEALEY'S POLLUTION LIABILITY REPORT 31 (2000) (discussing the *Daubert* challenges). *See also generally* Melissa B. Tearney & Janie L. Vowles, *Theresa Canavan's Case: SJC Rules on Admissibility of Expert Testimony,* 45 BOSTON BAR J. 12 (2001) (summarizing multiple chemical sensitivity cases that have been tried in Massachusetts, focusing on the Theresa Canavan Case, 432 Mass. 304 (2000)).

163. Diane Lofgren v. Motorola, 1998 AZ CV 93-05521 (Consol.), Super. Ct. (1998).

164. *Id.* at 2.

165. *Id.* at 65.

166. A discussion of qualifications of an expert and whether the expert's expertise properly fits the issue of the case is not the subject of this Article. The literature is replete with opinions on this matter, for example, see Roger Beers, *Legal Considerations Pertaining to Petroleum Hydrocarbon Contamination- Supplemental Materials,* chs. 5 & 6, *in* LEGAL AND TECHNICAL ISSUES SURROUNDING HYDROCARBONS (1997).

167. *See generally* Richard Bjur & James T. Richardson, *Expert Testimony Involving Chemists and Chemistry, in* EXPERT WITNESSING- EXPLAINING AND UNDERSTANDING SCIENCE 67 (Carl Meyer ed. 1999).

168. Meyer, *supra* note 82, at 102.

- The theory is related to the issue before the court,
- The theory is properly applied,
- There is sufficient data to support its application,
- The expert witness understands the theory and can effectively communicate it and its application to the audience,
- The judge rules that the scientific opinion is relevant and reliable, *i.e.*, admissible,
- The theory and the expert appear credible,
- Counsel promote the opinion correctly,
- Opposing counsel understand the theory sufficiently to bring out latent bias or error,
- It fits into the decision matrix of the trier of fact, and
- The trier of fact perceives the impact of science correctly."[169]

To the extent possible, the use of standardized tests, procedures, and document control procedures will promote admissibility of testimony. USEPA has recently been developing a QA system applicable to all its programs, which should improve the admissibility of its data or data generated using USEPA methods.[170] In addition, USEPA has published peer review guidance to enhance the quality and credibility of its technical work products.[171] Some

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169. *Id.* at 102-103.

170. *See generally* Lambert, *supra* note 88 (suggesting alternatives for assuming that all nondetects are zero, as a way to obtain better testing results). *See also* George M. Brilis et al., *Quality Science in the Courtroom: U.S.EPA Data Quality and Peer Review Policies and Procedures Compared to the Daubert Factors,* ENVTL. FORENSICS 197, 200-201 (2000) (demonstrating how EPA's current QA system matches up with the Daubert factors).

171. *See generally* OFFICE OF SCIENCE POLICY, U.S.ENVTL. PROTECTION AGENCY, SCIENTIFIC POLICY COUNCIL HANDBOOK, PEER REVIEW HANDBOOK (1998), *available at* http://www.epa.gov/ostwater/WET/pdf/prhandbk.pdf. The importance of a quality peer review system has been espoused by many associated with scientific research. *See, e.g.*, Michael Gough & Steven Milloy, *Policy Analysis: The Case for Public Access to Federally Funded Research Data, Cato Policy Analysis* No. 366,

states are also attempting to upgrade and standardize their own QA programs.[172] This same approach to consensus standardization is also recognized by professional organizations such as ASTM.[173] These considerations also apply to sample collection activities.[174]

The use of nonstandard methods can be more problematic from the standpoint of admissibility. Unfortunately, forensic chemists often need to use nonstandard methods when analyzing for unique marker compounds and mixtures. To be successful, the forensic investigator should consider using methods which closely mimic, or are modifications to, standard methods, whenever possible. In addition, data quality objectives should be established prior to initiating a sampling and analysis program, QA and QC procedures and limits should closely parallel standard protocols, and experienced forensic chemists should be directly involved with the work.[175]

CONCLUSION

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available at http://www.cato.org/pubs/pas/pa-366es.html for the results of the Cato Institute Study released in 2000.

172. For example, Massachusetts Department of Environmental Protection has convened a workgroup of state regulators, site investigators, and laboratory directors to promulgate consensus QA standards. *See* Jim Occhialini, *MCP Data Quality Enhancement Workgroup Update & Progress Report* 7 LSPA News 7 (Oct. 2000).

173. *See* John J. Lentini, *Standards Impact the Forensic Sciences* 29 ASTM STANDARDIZATION NEWS 16, 17-18 (Feb. 2001) (stating that the consensus standards are high quality).

174. *See, e.g.*, Harry F. Klodowski, *Legal Considerations in Sampling*, *in* PRINCIPLES OF ENVTL. SAMPLING 63 (Lawrence H. Keith ed., 2nd ed. 1996).

175. *See, e.g.*, WALTER BERGER ET AL., ENVTL. LABORATORY DATA EVALUATION 3-23 (1996) (providing guidelines for admissibility of evidence, including the expert's qualifications, the techniques' acceptance and the extent the technique relies on the subjective interpretation of the expert). *See also* Ann Rosecrance & LaDonna Kibler, *Guidance for Generating Legally Defensible Data*, presented at SUPERFUND XV CONFERENCE (Wash. D.C., Nov. 29-Dec. 1, 1994).

Success in pursuing an environmental forensic investigation may pivot on data produced in support of the study. Using representative data of known quality and integrity is paramount to making scientifically sound decisions that can be defended and ultimately be admissible in court. It behooves investigators and litigators to construct forensic chemistry programs, when applicable, with clearly defined data quality objectives, and to ensure that the chemistry program is conducted properly. Lastly, chemistry data produced by others should be closely scrutinized. The adage "assume nothing" is certainly apropos in environmental forensics.