INTRODUCTION TO ENVIRONMENTAL FORENSICS

SECOND EDITION

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INTRODUCTION TO ENVIRONMENTAL FORENSICS
SECOND EDITION

Edited by

Brian L. Murphy and Robert D. Morrison

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TABLE OF CONTENTS

INTRODUCTION TO THE SECOND EDITION

Since the publication of the first edition of *Introduction to Environmental Forensics* in 2002, the science of environmental forensics has matured appreciably. In 2005, *Environmental Forensics: A Contaminant Specific Guide* was published in the forensic series by Elsevier with the intent of providing the user with a means to access the forensic methodologies on a contaminant-specific basis. In contrast, this edition of *Introduction to Environmental Forensics* is designed to provide the reader with a methodological organization of the forensic tools available and as a complementary reference to the *Contaminant Specific Guide*. Additional forensic methods in this second edition include chapters on laser ablation inductively coupled mass spectrometry (LA-ICPMS), manual- and computer-controlled scanning electron microscope (SEM) techniques and x-ray diffraction, pattern recognition methodologies, expanded chapters on sampling techniques and statistical methods, and a presentation of several emerging forensic techniques. In this edition and subsequent editions of *Introduction to Environmental Forensics*, methods of general applicability will be emphasized and the *Contaminant Specific Guide* will provide forensic approaches for specific contaminants. We would be grateful to readers for suggestions for improvement.

"Forensic" is related to "forum" and refers to any public discussion or debate. In the United States "forensic" most often refers to courtroom or litigation proceedings. However, environmental forensics may also provide the fact basis for mediated or negotiated transactions or for any public inquiry related to environmental matters. Questions that environmental forensics seeks to answer are:

- Who caused the contamination?
- When did the contamination occur?
- How did the contamination occur? (For example, was it an accidental spill or a series of routine operating releases?)
- How extensive is the contamination?
- Are the test results valid? Is there evidence of fraud?
- What levels of contamination have people been exposed to?
- Can environmental forensics assist in allocating remediation costs?

The contexts of environmental forensic investigations include liability allocation at hazardous waste sites where multiple parties are involved, site assessments for property transfers, insurance litigation, toxic torts, and cost allocation among multiple parties found liable for releasing contaminants into the environment.

Environmental forensic investigations frequently deal with the historical release of contaminants. Generally there are two sources of information in conducting an investigation, namely:

- The documentary record, including statements by witnesses or other knowledgeable individuals, aerial photographs, insurance maps, and electronic information copied from computer hard drives, and
- Measurement or sampling data.

Once the historical information has been acquired and evaluated, one can then identify which forensic technique is most suited for answering the forensic question(s) of concern and how to appropriately use the selected methodology. For example, chemical or isotope concentration data can be used in different ways to answer forensic questions, including

- Tracer techniques based on the presence or absence of a particular chemical.
- Ratio techniques where the relative amounts of two or more chemicals are compared.
- Trend techniques where the spatial or temporal variation of a concentration, or a ratio, is of interest.
- Quantity techniques that depend on the integrated concentration over space or time, i.e., the mass of a chemical, to provide forensic information.

A forensic investigation may involve multiple forensic techniques and applications that are evaluated to answer the forensic question of interest. For example, identifying the source of and age dating a hydrocarbon spill may be of interest. The presence or absence of lead, methyl tertiary butyl ether (MTBE), or other additives, for example, may provide this crucial information that provides insight regarding the source or age of the release. The ratio of different hydrocarbon componants or octane readings may provide the basis to distinguish different fuels or brands. The spatial variation of a contaminant plume or its growth over time may assist in both source identification and age dating. Finally, the total mass or volume of petroleum hydrocarbons in the environment may be compared to inventory or leak detection records for source identification.

The most successful forensic investigations rely on the approach of selecting the most applicable techniques from numerous methodologies. An investigation relying on the results of a single forensic technique, exclusive of other available tools, is frequently successfully challenged when contrary evidence based on multiple forensic approaches is introduced. When forensic evidence is arrayed as multiple, but independent lines of evidence, a stronger scientific case, less susceptible to scientific challenge, emerges. This book is intended to provide you with your own toolbox of forensic techniques.

Brian L. Murphy

Robert D. Morrison

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EDITORS

Robert D. Morrison, Ph.D. is a soil physicist with over 36 years of environmental consulting experience. Dr. Morrison has a B.S. in Geology, an M.S. in Environmental Studies, an M.S. in Environmental Engineering and a Ph.D. in Soil Physics from the University of Wisconsin at Madison. Dr. Morrison published the first book on environmental forensics in 1999, is the editor of the Environmental Forensics Journal and is a co-founder of the International Society of Environmental Forensics (ISEF). Dr. Morrison specializes in the use of environmental forensics for contaminant age dating and source identification.

Brian L. Murphy, Ph.D. is a Principal Scientist at Exponent. He is the coeditor of Environmental Forensics: Contaminant Specific Guide, also with Robert Morrison. He is the author of more than thirty journal publications and is on the editorial board of the journal *Environmental Forensics*. Dr. Murphy has an Sc.B. from Brown University and MS and Ph.D. degrees from Yale University. All his degrees are in physics. He has spent most of his career as an environmental consultant, including as General Manager for Physical Sciences at what is now ENSR, founding President of Gradient Corporation, and Vice President of Sciences International. He also has had Visiting Instructor positions at Harvard School of Public Health and the University of South Florida. His practice focuses on using environmental forensics to reconstruct

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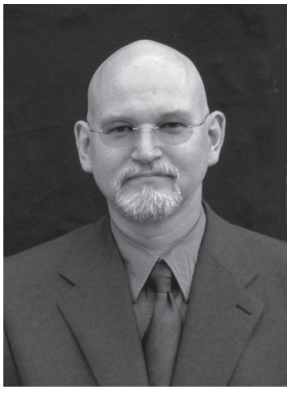
Shelley Bookspan, Ph.D. is currently a consultant in Santa Barbara, California. In 1982, she was among the founders of PHR Environmental Consultants, Inc. She is past president of PHR, which pioneered the application of historical methodology to pollution liability matters. Dr. Bookspan's doctorate, from the University of California, Santa Barbara, is in history, with emphasis on American history, history of technology, and urban history. She also holds a master's degree in city planning from the University of Pennsylvania and a master's degree in history from the University of Arizona. Dr. Bookspan is widely published both in the fields of history and environmental consulting, and she is now working in multimedia presentation and video production.



Richard Brown, M.S. is a microscopist and an Executive Director at MVA Scientific Consultants in Atlanta, Georgia. Since 1989 Rich has applied light and electron microscopy to small particle problems in the Environmental Forensics field to characterize and identify the particles and determine their source(s). Rich received his Master's degree in Forensic Chemistry and worked as a Criminalist doing crime scene investigation and trace evidence examination at the Orange County Sheriff-Coroner Department in Santa Ana California. Rich has testified in court as an expert witness and is a member of the California Association of Criminalists, the American Academy of Forensic Sciences and is a diplomate of the American Board of Criminalistics.

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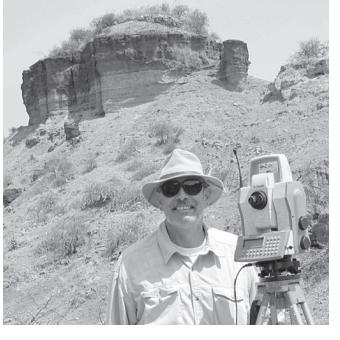
Gregory S. Douglas received M.S. and Ph.D. degrees in Oceanography from the University of Rhode Island and has over 25 years of experience in the field of environmental chemistry. He has designed, implemented, managed, audited, and defended a wide range of environmental forensic chemistry studies for government and industry concerning complex petroleum and fuel contamination issues in marine and soil/ground water systems. Dr. Douglas has performed extensive research concerning the fate of gasoline NAPL and gasoline additives in groundwater. He has prepared interpretive reports on more than 100 site or incident investigations involving petroleum product source and age dating issues, and has published and presented on the development and application of environmental forensics analytical methods, source identification and allocation within complex contaminated environments.



James I. Ebert, Ph.D. is an archaeologist, anthropologist, and forensic scientist. He is Chief Scientist at Ebert & Associates, Inc., an Albuquerque, New Mexico firm specializing in forensic, environmental, and archaeological applications of photogrammetry, photo analysis, remote sensing, and digital mapping and imaging technologies. He is a Certified Photogrammetrist (American Society of Photogrammetry and Remote Sensing), a fellow of the American Academy of Forensic Sciences, and a member of the New York State Police Medicolegal Investigations Unit. Since 1989 Dr. Ebert has conducted ongoing archaeological and environmental research at Olduvai Gorge in Tanzania with Rutgers University's Olduvai Landscape Palaeoanthropological Project.

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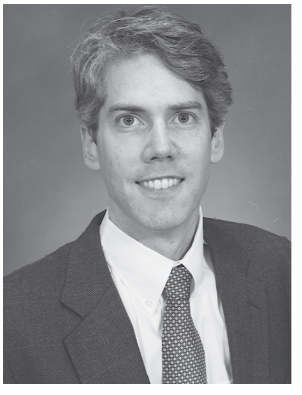
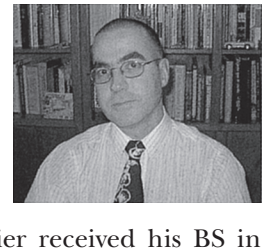


Stephen Emsbo-Mattingly holds an MS in Environmental Science from the University of Massachusetts and more than 18 years of experience in environmental chemistry and forensics. He specializes in the identification of tar, creosote, petroleum, PAHs, PCB, PCP, solvents, and other compounds of concern in various media. Mr. Emsbo-Mattingly's recent research and publications focus on the formation and weathering of PAHs and PCBs with an emphasis on the transfer of source signatures between sediment, tissue, and vapor phases. His investigations often involve the simultaneous identification of various other contaminant sources, like non-point releases from storm sewer discharges and wastewater treatment plants. Most of these projects use historical laboratory data, multivariate statistics, and GIS-based spatial analysis.

William E. Full, Ph.D. has spent his career in academia and industry focusing on computer applications and algorithm development in the geosciences. He has B.S. in mathematics from the University of Notre Dame, and M.S. and Ph.D. degrees in Geology from University of Illinois, Chicago and the University of South Carolina, respectively. In 1982 he received the Andre Borisovich Vistelius Research Award for Young Geomathematicians from the International Association of Mathematical Geology. He has published many papers on information entropy and multivariate analysis, and he was the principal developer of the Polytopic Vector Analysis procedure. Dr. Full was on the faculty of the Department of Geology at Wichita State University for 15 years, and is currently a Distinguished Professor at the University of Rome, Italy, and President of WEF consulting in Wichita, Kansas.



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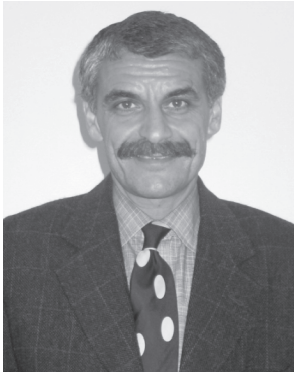

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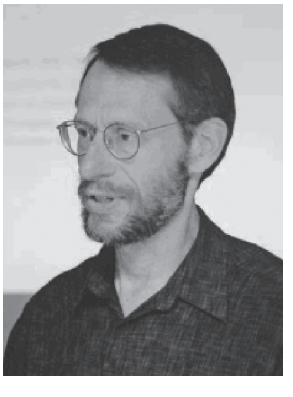
Ioana Petrisor, Ph.D. has a PhD in Biology/Environmental Biotechnology from Romanian Academy of Sciences (awarded in 2000) and a Bachelor in Chemistry with a Major in Biochemistry from Bucharest University in Romania, Faculty of Chemistry (awarded in 1992). In December 1999 she has completed an UNESCO training program (3 months) on Plant Molecular Genetics at the University of Queensland, Department of Botany in Brisbane, Australia. She is co-author of 63 scientific papers published in peer-review Journals and Proceedings and of one invention patent. She has more than 12 years of experience (both academic and industry) in the Environmental Engineering/Biotechnology field. She is Managing Editor for the Environmental Forensics Journal and a member of the Editorial board of several other peer-review Journals. She was recently elected as Vice-Chairman of the newly formed ASTM committee on Forensic Environmental Investigations (subcommittee of Environmental Assessment, Risk Management and Corrective Actions main E50 committee). She is a member of ACE, AEHS, ITRC (Vapor Intrusion and UXO teams) and other professional organizations. Her work experience includes managing and conducting innovative research (at lab, field and pilot scales) for U.S. DOE and the European Community on the topics of bioremediation and phytoremediation, environmental characterization and risk assessment. She is now involved in forensics studies aiming to identify the source and age of contamination, and subsequently allocating responsibilities between different potential responsible parties for case studies involving gasoline and other petroleum products releases, PCB contamination, as well as chlorinated solvents and heavy metals.

R. Paul Philp, Ph.D. is Professor of Petroleum and Environmental Geochemistry at the University of Oklahoma. He received his Ph.D. from the University of Sydney, Australia in 1972 and a D.Sc. from the same University in 1998 on the basis of his research in geochemistry over the past 20 years. Prior to starting at the University of Oklahoma in 1984 Dr. Philp was a Principal Research Scientist, C.S.I.R.O., Sydney, Australia. His current research interests center around petroleum, environmental and forensic geochemistry with an emphasis on molecular and isotopic characterization of oils, gases, rock extracts and contaminants for the purposes of source determination, characterization of depositional environments, maturity, biodegradation and for correlation purposes. Much of the current research activity in the area of forensic geochemistry involves the use of stable isotopes for the purposes of fingerprinting contaminants in the environment for correlation purposes; source determinations and evaluating whether or not natural attenuation is active. This approach is particularly valuable in the case of refined products or single component contaminants when the more traditional GC and GCMS techniques are of little or reduced use. He has authored or co-authored over 340 articles and books and has lectured extensively on petroleum and environmental geochemistry in SE Asia, South America, Europe and Africa.



Scott Ramos, Ph.D. is an analytical chemist with experience in environmental and trace hydrocarbons, natural products and chemometrics. He has a B.S. degree in chemistry from MIT, an M.S. in environmental science from Washington State University, and a Ph.D. in analytical chemistry and chemometrics from the University of Washington. Scott has worked for NOAA's National Marine Fisheries Service, in Seattle, at FEEMA, the state pollution control agency in Rio de Janeiro, and the federal Amazon Research Institute (INPA) in Manaus, both in Brazil. During the last 22 years, he has been the chief scientist at Infometrix, Inc, in Bothell, WA. Publications include studies on contamination by polycyclic aromatic hydrocarbons, essential oil characterization, and various applications of chemometrics.

Charles Ramsey is the founder and President of EnviroStat, Inc., a company that provides training in sampling and laboratory subsampling for defensible environmental decisions to federal and state agencies as well as private companies. He has a BA in Chemistry from the University of Denver and a MS in Environmental Science from the Colorado School of Mines. Mr. Ramsey has 20 years sampling experience including seven years with the National Enforcement Investigations Center (NEIC) of the USEPA. While with the EPA, Mr. Ramsey provided sampling and statistical expertise on all major environmental regulations. Mr. Ramsey is involved with the development of guidance documents for sampling and statistics.

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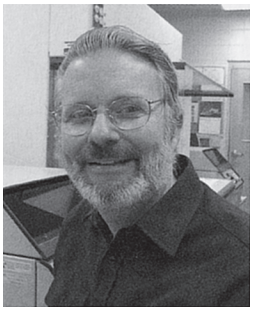

John G. Watson, Ph.D. is a Research Professor in the Desert Research Institute's (DRI's) Division of Atmospheric Sciences specializing in the characterization, source apportionment, and control of suspended particles that cause adverse health effects and regional haze. Dr. Watson has developed theoretical and empirical models that, when coupled with appropriate measurements, quantify contributions for pollution from different sources. With his colleagues, he has applied these

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