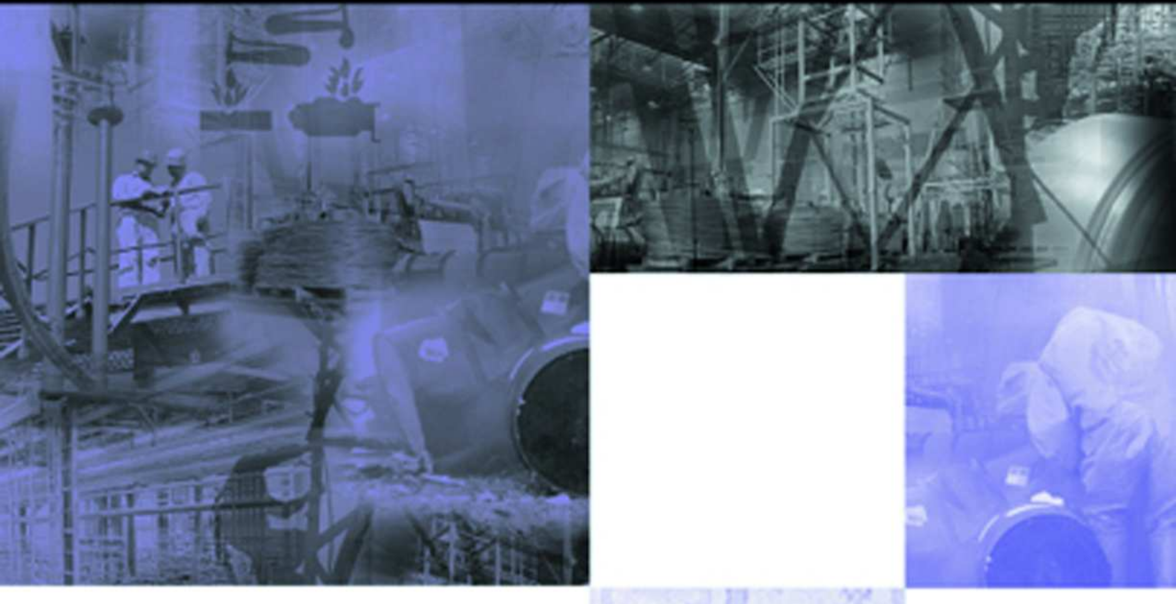
Daniel A. Vallero



Engineering the Risks of Hazardous Wastes

WITH A CONTRIBUTION BY J. JEFFREY PEIRCE

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For Janis, the love of my life.

For my children, Daniel and Amelia, who are constant reminders of why environmental stewardship is so profoundly important.

To my ever-supportive mother, Berniece.

And, to my late father, Jim, my late uncles Louie, Joe, and Johnnie, and their fellow miners at the Lumaghi Coal Mine in Collinsville, Illinois, who lived with—and may have died from—hazards far beyond anything that I have yet to study in the laboratory.

View of a partially plug slope entrance to the Lumaghi Coal Company Mine Number 4 in Collinsville, Illinois in 1982. The entrance has since been plugged and backfilled, and the mining site has been remediated under the Illinois' Abandoned Mined Lands Reclamation Program. (Photo used with permission, courtesy of Illinois Department of Natural Resources.)

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Contents

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Foreword

Hazardous wastes are not a new problem; they have been a major environmental problem for centuries. As people learned to process certain natural materials to yield various metals that were useful in many ways, they soon learned that the residues from the production of the different metals were toxic to biologic life. Plants did not grow as well in soil containing the waste residues from metal production. As time passed, plants no longer grew in the areas where the waste residues were deposited. Over time, the toxic waste volumes grew larger. Rain falling on the waste residues dissolved some of the toxic ions left in the residues, creating liquid runoff that followed the natural terrain to the nearest drainage ditch. Eventually, the toxic liquid moved into adjacent creeks and streams. As the concentrations of toxic ions increased, fish began to die. Eventually, all biologic life in the creek near the waste residue piles disappeared.

Authorities accepted damage to the environment as part of the cost to be paid for the advances in technology that the metal production had created. When the damages became too great, the authorities simply closed down the metal production facilities and had them moved to a new site. The environmental pollution problem began all over again on clean soil. The danger to people who worked in the early metal-processing facilities was recognized by both the authorities and society as a whole. Although the processing facilities were managed by high-level personnel, the operations were carried out by the lowest level of society. The metal-processing operators were considered as expendable for the greater good. Like it or not, decisions were being made regarding the risks to people and the impact of hazardous wastes on the immediate environment.

As populations increased, people occupied all the available land areas. There was simply no place to move to that could be used to process natural materials into useful products with the corresponding toxic waste piles. As the wastes continued to accumulate, something had to be done to prevent significant damage to the natural environment and to the people working and living around the manufacturing plants, which were producing hazardous wastes. It is interesting that some industrial plant managers still believe that wastes are a natural part of manufacturing that society must accept. This view is especially true in developing nations, where financial resources are limited.

The development of the chemical industry produced new sets of toxic waste materials. Some of the toxic waste materials were discharged into the air. Other toxic wastes were discharged as liquid wastes into nearby bodies of water or as solid wastes on the land. Rainfall on the solid waste piles produced additional water pollution problems. Solving the problems of an ever-growing modern society created additional forms of toxic wastes that spread over the entire environment. Although modern technology created the toxic waste problems, modern technology also developed the ability to remove most of the toxic materials from plant wastes. Unfortunately, removing the toxic materials from plant wastes did not improve the final products, but it did increase the cost of the final products. Because plant managers wanted to minimize their product costs and maximize their profits, the real problem for plant managers lay in minimizing waste production since few manufacturing plants could eliminate all wastes. The overall objective was to reduce the discharge of toxic wastes to levels below those determined to pose a significant danger to important life forms in the immediate environment. Society has yet to solve this problem.

Environmentalists changed our vocabulary from *toxic wastes* to *hazardous wastes*, in order to increase the public's awareness of the dangers from toxic waste discharges. The words *hazardous waste* carried a greater significance than the words *toxic wastes*, which were readily accepted as part of normal operations. It is interesting how words can change our perception of the world around us. Ideally, society would like industries to manufacture goods without producing any hazardous wastes. Unfortunately, it is not possible for all industries to produce zero hazardous wastes, but it is possible to minimize the production of hazardous wastes. One of the tools to help minimize the production of hazardous wastes is called risk assessment. Risk assessment techniques are useful in helping people understand the impact of different levels of hazardous wastes being discharged into our current environment and the potential damages that can be expected over time. Risk assessment is essential for environmental pollution control specialists to set waste discharge levels for the different hazardous components.

Once the allowable hazardous waste discharge quantities have been determined, environmental engineers examine the various treatment systems to remove the hazardous contaminants from all the different waste streams. Inorganic contaminants are removed by physicochemical methods, whereas organic contaminants are removed by various biologic treatment systems. Even photochemical methods are useful with specific contaminants. Environmental scientists play a major role in evaluating the different treatment methods used to remove the hazardous contaminants. Environmental engineers take the basic concepts developed by environmental scientists and design the treatment systems required to remove the hazardous contaminants. Sometimes environmental engineers construct large-scale pilot plants to demonstrate which treatment concept offers the best potential for success. Pilot plants can help illuminate potential problems that might arise in full-scale treatment systems.

Once the engineers have selected the optimum process, they must design the full-scale treatment system and select all of the mechanical equipment to be used. The engineers supervise construction of the full-size treatment units and placement of all mechanical equipment. Once the construction phase is complete, the environmental engineers start the treatment facilities and demonstrate the effectiveness of the treatment systems to remove the desired amounts of contaminants. The final step for the environmental engineer is training the treatment plant operators to ensure correct operation of the waste treatment facilities. Responsibility for day-to-day operations rests with the treatment plant operators and their immediate supervisor. Removal of the hazardous components from the various waste streams and their proper processing for return to the environment is a major responsibility that requires competent, dedicated individuals who can meet the challenges.

The author has chosen to focus this book on the most critical phase of hazardous waste engineering, the engineering of risk management for various types of hazardous contaminants. Understanding risk management is critical to the control of hazardous waste materials for environmental engineers. As one of Dr. Vallero's professors at the University of Kansas and as a colleague at Duke University, it has been a special pleasure to watch his professional development and growth over the years. All older university professors will recognize the special pride faculty members take in seeing the products of a former student's efforts. Knowledge is built on a solid foundation and constructed from the sum of a lifetime of experience.

If you learn to manage the hazardous waste risks, you will also learn to manage life's risks. Knowledge is not designed to be kept in a single box, but rather is designed to grow and blossom throughout the full expanse of life.

Thank you very much, Dan.

Ross E. McKinney
Adjunct Professor, Duke University
Professor Emeritus, Kansas University

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Preface

The control and management of hazardous wastes are truly among the most important challenges of our times. Environmental engineers play crucial roles in reducing the amount of hazardous substances produced, treating hazardous wastes to reduce their toxicity, and applying sound engineering controls to reduce or eliminate exposures to these wastes. The calling of engineers is broad. We design the facilities that generate the chemicals that, under the wrong circumstances, become hazards. Once the wastes are released, we are asked to design and operate the containment and treatment facilities to deal with them. We are the professionals who are most frequently called on to address these wastes once they are released into the environment.

There are seldom, if ever, single solutions to environmental problems, especially hazardous wastes. "Everything matters in environmental engineering."[1] To deal with hazardous waste, the environmental engineer must have a command of the physical sciences. It would be imprudent to respond to the release of a chemical without first ascertaining its physical and chemical properties (e.g., first responders are well aware of the consequences of spraying water onto a strong oxidizer or failing to contain an organic compound that has a very high vapor pressure). The physical characteristics of the environment must also be known. For example, how quickly will a spilled substance traverse the vadose zone? What is the recharge rate of the aquifer? The natural and biologic sciences are also requisites to comprehensive hazardous waste management. How toxic is the substance to humans or sensitive species? Does it accumulate in the food chain?

The environmental engineer must also consider the sometimes less obvious fields of the social sciences and the humanities. Is one solution more cost effective than another? How were these costs determined? How does one (or, more important, *should* one) place a value on a human life, or the lost aesthetics, or the fears of nearby residents? These are not solely theoretical constructs. Environmental engineers are confronted daily with the controversies of real and perceived hazards. The well-trained engineer is prepared academically and professionally to incorporate the many engineering disciplines (and those of the social sciences and humanities) to be truly responsive to the challenges arising in the emotionally charged milieu of hazardous waste engineering. How we as environmental engineers decide what is important and how well we confront the problems of hazardous waste will dictate the public's perception of our success as environmental engineers for decades to come.

What This Book Is About

This book provides approaches for incorporating risk assessment and management into hazardous waste engineering decisions. It is intended to be the primary text for an undergraduate-level course in hazardous waste engineering and management, as well as the primary text for an undergraduate or graduate engineering and science course devoted to environmental risk assessment and management, with a particular emphasis on the risks posed by hazardous wastes. To cover the material in one semester, students should be grounded in basic physics and chemistry and somewhat familiar with fluid mechanics and the basic concepts of environmental engineering. This book can also be a supplemental or complementary text for a graduate-level hazardous waste engineering seminar, where a specific focus on risks is desired (I advocate that *any* hazardous waste engineering course include a risk module).

The book is also a reference for the practicing engineer and environmental scientist with an interest in risk assessment. Whether it is used as a textbook or as a reference, the book is designed to provide risk assessment insights to complement the physical and natural science considerations covered in a hazardous waste handbook.

The book can also be useful to a more general audience. It is a resource for an interested and informed reader, yet the reader does not necessarily have to be a practitioner in the field of hazardous waste site remediation or a risk expert. For example, all industry-related jargon and any terminology not widely applied outside of the environmental engineering profession is defined in context. Callout examples, case study discussions, and definitions appear throughout the text to clarify important engineering and risk concepts. This approach is necessary even within the field because environmental engineering has an eclectic mix of perspectives. Therefore, environmental consultants, public interest groups, and neighborhood groups should find this book useful, understandable, and beneficial as they address or learn more about the various aspects of hazardous waste issues.

What This Book Is Not About

This book is not a hazardous waste handbook *per se*. There are many excellent resources out there and probably more coming.[2] This book is a companion to such handbooks and manuals. I address several hazardous waste issues and, in doing so, I consider hazardous waste technologies and processes. In fact, Professor Peirce's excellent contribution to this book (Chapter 4) provides some real-life engineering approaches for engineers to intervene to address hazardous wastes; however, it should not be inferred that this is an exhaustive treatise on hazardous waste engineering techniques. Similarly, this book is not a physics or chemistry text, although I draw heavily from these fields in Chapter 3 and many of the case studies. I use these materials in a senior environmental chemistry course that I teach at North Carolina Central University. Finally, this book is not a philosophy or ethics text; however, hazardous waste engineering is rich in moral and ethical issues and lessons, so I would be remiss not to point these issues out along the way.

In all matters surrounding hazardous wastes, the specific circumstances must dictate the appropriate engineering approach. One size does not fit all! Therefore, this text does not prescribe specific remedies for any single problem. The problem must be considered in light of the scientific, engineering, societal, and legal aspects of each hazardous waste problem. Thus, the appropriate response will vary in each circumstance, depending on the particulars.

September 11, 2001

Like so many other endeavors of 2001, my research and thought processes related to this book were drastically changed following the attacks of September 11, 2001. The book is very different from what it would have been had the United States not been attacked. First, because I have been personally involved in the environmental monitoring around the World Trade Center (WTC), I have used some of the lessons learned from the environmental emergency response to write Chapter 6. The WTC has provided important lessons to environmental engineering that may be applied to more general hazardous waste projects. Second, I have become more aware of the important new roles for environmental engineers in large-scale emergency response efforts. The book now includes new insights regarding how risk-assessment techniques can assist environmental engineers with their new responsibilities to protect our public health. Finally, I recommend a higher profile for environmental engineers as members of the civil engineering community. For example, much that has been written about the roles of civil engineers in responding to September 11 has been devoted to structural considerations for existing and planned buildings and infrastructures.[3] This concern is certainly paramount, but it is not the only one for civil engineers. All engineers who specialize in environmental concerns are also key players in emergency response. In fact, many of the questions and concerns that have arisen as people begin to return to their homes near Ground Zero are related to human health risks, such as exposure to asbestos, lead, or other hazardous substances.