Foreword

The Industrial Revolution, which started in the United Kingdom during the nineteenth century, may have been the birth of the Industrial Age, but the manufacture of coal gas as a prime energy source has been a prime mover in changing the face of the earth. We within the United Kingdom feel a key paternal role in the discovery, development, and spread of gas-making technology, largely through its keen acceptance by the Americans as well as our neighbors throughout continental Europe and eventually the developing world as a whole. While gas lighting and power forged a vast link between technology, industry, and society itself, which brought wealth to many and health to most, the concept of sustainability was not in those days an issue.

Manufactured gas sites are complex both in their processes and structure as well as in the residues left behind on abandonment and demolition. The contamination, both potential and actual, is still not fully understood. The early–emergent awareness of gas-making residues as contaminants has now fully blossomed and the unique blends of detrimental qualities of gas tars, their "liquors," and associated heavy metals, spent oxides, and other health-detrimental elements and compounds command our attention as do few other environmental remediation needs, save, perhaps, for the various chlorinated compounds.

It was again in Britain that the technical recognition of town gasworks remediation was launched, with the publication of the *AEC-Harwell* handbook in 1971, as it was that Peckston's 1819 handbook served as the master published guidance for many decades.

To continue this work, we need to bring together the mass of information around the developed world to aid our understanding. It is, therefore, a pleasure to take note of Professor Hatheway's efforts to assimilate this compendium of what is essential in considering various remedial alternatives to address today's environmental threats from such an elegant and complex historic technology as manufactured gas.

Hatheway is a come-alive disciple of the ancient gas men. He has accepted a natural challenge to bring their compound knowledge back to the forefront, for scarcely any gas men are still alive and the preponderance of knowledgeable authors of their technology have all passed on.

This book is nearly encyclopedic. The author has personally compiled some 200 separate tables of facts and associations that are meant to clarify corresponding and interrelated conditions and factors necessary to define site-specific gas plant conditions. Photographs, historic drawings, and his glossary are essential to our working understanding. Each and every person concerned with today's coal-tar threats will find it easy to understand the common basis for the deliberations that are needed to assess and manage gasworks' environmental threats.

While robust and innovative solutions have been achieved in the commercial arena, and we have demonstrated that old coal gas works can be brought back into beneficial use, Hatheway gives us an essential tool to help us rise and meet today's gasworks environmental challenges.

Engineers, scientists, and historians alike will here find the common ground of environmental assessment. Hatheway does not rob us of our individual roles as environmental professionals, he merely provides the tools for our considered works. Together, we should be one step nearer to reclaiming the land, which was the legacy of our "grandfathers," for reuse to fuel the Post-Industrial Age, but in a more sustainable way.

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Acknowledgments

The compilation of this book occupied a good deal of my consciousness for more than a decade. During this time, I encountered many outstanding people who either or both knew something of manufactured gas or cared about the need to deal with its environmental legacy. Some of these persons were students of mine, who in the course of my site and waste characterization and remedial engineering teaching, were subjected to a running diet of coal-tar technologies (both old and remedial), examples, tidbits, and provocative projects dealing with the discovery, evaluation, and planning necessary to carry on worthwhile gasworks remediation.

Others, such as the late John L. Buchanan (1915–2002), gregarious, sharp-as-a-tack master coke-oven superintendent, became close friends, and was asked by the author to lecture at the School of Mines and Metallurgy, University of Missouri–Rolla. In fact, John, then at age 84, lectured steadily and inspiringly, for two hours, without notes and while being videotaped! Still others, who may not have been as close, but yet who were outstanding role models, visited to lecture to the students. These were people such as Harry Horey, PE, former chief engineer of the Laclede Gas Company (St. Louis); David Pluhar, PG, then of Union Electric Co. (St. Louis); James Gould, PG, PE, former officer of ReTec, Inc.; Richard Nussbaum, PE, and Tim Lacy, chemist, both of Missouri DNR; Commander (Dr.) Peter Culver, PE (U.S. Public Health Service, attached to U.S. EPA Region VII); James Callier, PE (U.S. EPA Iowa office); Dion Novak, PE (U.S. EPA Region V); and David Mafiewski (U.S. EPA Region VI, Dallas)—all together came through with lessons learned and sensitivities being recognized by the utility industry, their consultants, and of the regulating agencies.

Meanwhile, I was visiting and studying former manufactured gas plant (FMGP) sites, ramping up to the number of 900, of various types, that I have subjected to scrutiny. In the course of this effort, I have been assisted by probably 150 remedial project managers (RPMs) of the federal EPA regions and nearly two-thirds of the state environmental agencies. Foremost of these folks, coming to mind, largely because of their high level of applied knowledge and their energies of focus (and the extended duration of my persistence), are Dr. Johanshir Golchin, PE, and Mick Leet, EIT (Iowa DNR); Jack Eslien, PG; Jamie Dunn, PG, and Jennifer Eastland, PG, of Wisconsin DNR; Gardner W. Cross, PG (NY DEC); Louis Blanck, RG, California State Water Resources Control Board (CA WRCB, Central Coast, Region 3), San Luis Obispo; Christopher A. Guerre, RG, CA DTSC, Region 4, Cyprus, CA; Julia E. Turney, CEG (late of Cal DOT); and Dr. Mavis D. Kent, PG (OR DEQ). Added to these folks are Jack Stewart, now-retired city councilman, and John Ruff, PE, city environmental engineer, both of Plattsburgh, New York.

In addition, many readers will already have known of me through the related Web site (www.hatheway.net), originated in 1993 by the late Ben Strehlmann, a graduate nuclear engineer and general computer whiz, then of the University of Missouri–Rolla (UMR) Computer Center staff. Ben passed that effort to my elder son, Major Brian A. Hatheway, U.S. Army, now of the Diplomatic Security Corps, U.S. Department of State. Since 2000, the Web site has been grandly expanded by Dan O'Brien, highly energetic, award-winning biology and forensic science instructor and head of science faculty at the Polson High School, Polson, Montana.

My visits to libraries have worn out several sets of vehicle tires, numerous shoe soles, and a few wallets. My greatest appreciation to technical libraries, however, goes to the Curtis Laws Wilson Library of UMR (Directed during by Chief Warrant Officer Andrew Stewart, U.S. Army Reserve; sometimes on duty in Iraq) and to the Linda Hall Library (LHL) of Science & Technology, Kansas City, Missouri. LHL, I must declare (in my opinion, based on my usage) has the finest assemblage of source materials on manufactured gas, at least in North America; probably so worldwide.

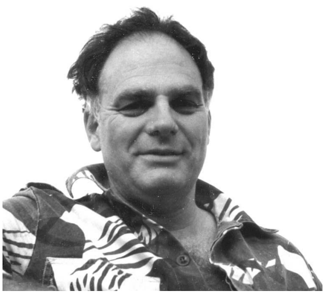
I must give great appreciation to my paying clients, whose trust has resulted in indirect (through fees for professional services) funding that I have utilized to carry on the adventures of search and discovery, and for the means for constant expenditures laid out to acquire background literature, images, drawings, maps, and associated gas industry memorabilia. In this connection, my greatest appreciation goes to John A. Guarascio, Esq., Robert P. Firriolo, Esq., Vanessa L. Bakert, Esq., and Dean Vigliano, Esq., all four of whom practice in New York City. And on the west coast, to Thomas Fellenz, Esq., of Sacramento, and to Brook Bond, Esq., late of San Francisco and now of Boise, Idaho. Both Firriolo and Fellenz are graduate civil engineers to boot! My appreciation goes out for the depth of understanding of these attorneys and for their particularly stimulating penetrating tasking and questioning of my findings and of my developed opinions and support materials.

From Great Britain, I cite my wholly worthwhile contacts, beginning with Peter Braithwaite, late of Arup, and retired serving gas engineers J. Barry Wilkinson, CE, and Terry Mitchell, CE, both arch leaders of the movement to preserve the memory and history of manufactured gas, and to Martin G. Culshaw, late director of engineering geology for the British Geological Survey, the latter for his concern about the need to apply good geology to the demanding task of gasworks site and waste characterization.

Lastly, and most importantly, my persistent gratitude goes to the companionship, support, stimulation, and editing provided by my wife, Diane ("Dina") Margaret Rydell Hatheway, an English language, American history, and literature enthusiast, journalist, and fellow travel junkie. Dina has helped me immeasurably with this book and much of my other technical writing. This, I humbly appreciate, along with her boundless energies, gourmet chef'ing, and her countless staunch friends, worldwide.

Allen W. Hatheway
Rolla, Missouri

Author



Allen W. Hatheway took early retirement from the faculty of the School of Mines and Metallurgy of the University of Missouri–Rolla (now Missouri University of Science and Technology), on the last day of 1999, after teaching geological engineering at that campus for nearly 20 years. He is a registered professional geologist and engineer in several states and has practiced for 50 years, half of it with prominent geotechnical and geoenvironmental consulting firms; he is also practicing on a solo basis. His specialties are site and waste characterization and remedial engineering for environmental litigation, mitigation of geologic constraints, and for hazardous waste cleanup, particularly of former manufactured gas plants. His Web site (www.hatheway.net), established in 1993, is meant to provide factual background for professional engineers and professional scientists, along with concerned citizens and members of the media, all directed toward people who choose to meet and resolve these coal-tar environmental threats.

Dr. Hatheway received his baccalaureate at UCLA and graduate degrees from the School of Mines of the University of Arizona. He has also, early on, held adjunct faculty appointments at the University of Southern California (civil engineering), at Boston University (geology), and at the National Defense University, Fort Lesley J. McNair, Washington, DC. He is a past chairman of the Engineering Geology Division of the Geological Society of America (1980) and holds its Distinguished Practice and Meritorious Service Awards, as well as the Burwell Award (for meritorious technical writing). In addition, he is past president of the Association of Environmental and Engineering Geologists (1985), from which he holds the Floyd T. Johnston Service Award and the Claire P. Holdredge Award (meritorious technical writing), and was elected an honorary member in 2002. Immediately upon taking early retirement, he answered the call to deliver the joint-society Richard H. Jahns Memorial Lectures ("Site Characterization") on 74 occasions, in the United States and Britain, in the first year of his retirement (2000). During his long membership in the American Society of Civil Engineers, he was named California's Outstanding Young Civil Engineer (1973), was awarded the Daniel W. Mead Award (1975), and was made a fellow and life member. He is retired from the U.S. Army as colonel of engineers (1991) and, among other military decorations, holds the Meritorious Service Medal with two oak leaf clusters. He is also a graduate of the Command and General Staff College (Ft. Leavenworth, Kansas) and the Army War College (Carlisle Barracks, Pennsylvania).

Hatheway strongly believes that experts should publish and share their knowledge for the betterment of all citizens and for transparency of their claimed expertise. Among his technical-book authorship are the CDR book *Perspectives on the Practice of Engineering Geology* (2005), currently under revision as a peer-reviewed expansion from 64 articles (436 pp.) to 100 articles. He also was the late Robert F. Legget's coauthor for the third edition (1988) of *Geology and Engineering.* From 2005 he served as the only elected chairman of the Joint Task Force on Areas of Practice for Engineers and Geologists; its work was completed in 2010.

Hatheway has visited, studied, and/or performed consulting on more than 900 coal-tar sites in North America and Britain and has performed geological fieldwork in most U.S. states and in Canada, the Caribbean, South America, Singapore, Myanmar, South Korea, southern Africa, Norway, the United Kingdom, and western Europe.

Introduction

This book was born of the frustration that I experienced in gaining definitive answers to real questions about site and waste characterization and remedial engineering of manufactured gas plants. As the frustration grew so did captivation by the topic itself. I came to believe, then know, then accept, then to be fascinated by manufactured gas as a great socializing and civilizing force in the Industrial Revolution and to see that gas was the great muscle of nineteenth-century industry and national might. And, at that, a force of consequence for nearly 50 years into the twentieth century.

My thirst and quest for knowledge of the manufactured gas industry began late in 1988, when I was referred to the Iowa Department of Transportation in its defense of utility company claims that construction activities of the then-new Mississippi River suspension bridge had released historic the gasworks contamination being then discovered in the "Big Muddy" (Mississippi River) offshore of the 1855–1952 gasworks.

Years into this quest for the character and truth of yesteryear's gas technologies and today's environmental concerns, I am convinced that more has been lost than is generally known about yesteryear's gas-manufacturing and related coal-tar knowledge. Even less of this recovered knowledge has been evaluated and set down as the empirical truths of the coal-tar situations that citizens, industry, and government face today. This knowledge needs to be rediscovered, reanalyzed, and applied not only to remediation but also to be made available for the poorly informed but concerned citizenry, our mass media, and our public leaders. With the truths before us we can set about correcting the implied and recognized environmental threats of these "coal-tar" sites.

Overwhelmingly apparent is the threat potential for any given former manufactured gas plant (FMGP). Each plant had extensive disposal of unwanted residuals, as well as the plant wastes, some of which are known carcinogens and soluble in water. Into the interstices of the solid waste dumps often flowed the toxic clarification waters of the gasworks. Gasworks tars themselves are a witches' brew of some 500–3000 separate polycyclical aromatic hydrocarbon (PAH) compounds, nearly all of which are dense nonaqueous-phase liquids capable of sinking through the vadose zone and deep into the groundwater regime. PAHs have the potential of contaminating groundwater at the ratio of a pint to a surface water oil slick or a quart to contaminate a quarter-million gallons of groundwater. Lastly, the vast bulk of gashouse wastes are nondegradable in nature and therefore have lives of tens of thousands to millions of years in the environment.

I began to write this book 13 years ago and have never dropped my quill. The content of this book has been arranged to identify, define, and explain necessary historic and contemporary information needed to plan, conduct, and interpret remedial site and waste characterization efforts at coal-tar sites. For this book, historic literature and site-specific sources were searched and carefully reviewed as the base material. The gashouse crowd had a lot to say in the print of their time. A good deal of the rich record of manufactured gas, coke, and coal-tar literature, however, has already perished in the trashing and weeding of the national public and university libraries. The literature now is largely rare and difficult to locate and access. Thankfully, in 2007, Google Books joined the efforts of Project Gutenberg and the Internet Archives to bring forth growing portions of noncopyright literature, including that of the manufactured gas industry.

I have purposefully avoided primary use of the relatively scant recent works by others, mainly those sponsored as level-of-effort works by the U.S. Environmental Protection Agency and by the American public utility industry. This tact seemed imperative in order that I face this now-ancient technology personally and head on. Information presented in this book comes directly from locating and dealing with historic sources as the primary database and by visiting as many old sites and locations of ongoing environmental activities as possible. The scientist-half of me doggedly went for the background information in order that the method of multiple hypotheses could be developed and used on a site-by-site basis. Extensive use of tables, each personally compiled, imparts the requisite dates, numbers, and resulting interpretations, just as an engineer gathers the basis for problem solution. Contemporary drawings and photographs were located to illustrate each individual aspect of historic information. My engineer-half continued the journey with unabashed distrust of assumptions in-lieu-of-facts, knowing that the parts of the equation of most-plausible solution are the means of building and solving the philosophical equation relating to each specific site.

The purpose of Part I (Background Information) has been "What does all this mean at a particular site?" Its eight chapters explain how manufactured gas, coke, and by-products were made, as well as how they and their residuals and wastes were typically managed. Always constantly on my mind was the need to excerpt quotes of the gas men, and so the book allows them to speak to us amply, and in their own words.

Part II (The Remediation Process), containing the remaining three chapters, deals with the evaluations and deliberations that make up the site remediation process. Every coal-tar site is unique, in terms of its own identity; its specific technological and operational history; and the goals, objectives, and competence of its operators, owners, and investors; and importantly, its geology. Add to this the particular situations that represent the bottom line of today's remediation concerns. How much is to be done in and toward remediation and who is to pay for such actions? These considerations represent an entirely different puzzle to solve. Here a vast envelope of considerations arise: site and waste characterization, state and federal environmental protection requirements, forms of risk assessment, remediation financing, public relations, seeing that the media receives the truth, legal considerations of due-process liabilities, and opportunities to seek cost recovery contributions from third parties. Sources for this second part of the book include a survey of the coal-tar remediation literature of this current era of environmental consciousness, supplemented by personal experience and observations, along with the contributions from other experts on today's "coal-tar circuit."

Nowhere do I mean to take a position of advocacy representing any special interests of the various types of parties to the remediation process. Engineers, scientists, regulators, public officials, and the public can seek information to assist in their own interpretations as to what actions, policies, or determinations may be required at individual sites and these, of course, will vary widely. This book should be considered a source book of information from the past, tempered with findings and influences of today. The very essence of this book is that no coal-tar site should be considered anything like any other coal-tar site. Every site is unique because all of them were operated by human beings with different goals and competencies. Also, the industrial processes involved generally varied over the period of operation. All of this went on above and in geologic ground containing unique arrangements of earth materials. The hallmark characteristic of today's coal-tar novice is to jump to conclusions based on incomplete study and evaluation of one site and borrow conclusions from another site, operated in another space, and at another time, by other people.

I came to teach at the University of Missouri–Rolla (Missouri School of Mines, 1870) as one of the few remaining solely technical universities in the United States in 1981. This followed an earlier career in consulting geotechnical and geoenvironmental engineering practice in Los Angeles, San Francisco, and Cambridge. I arrived at Rolla with "95% of the questions and 5% of the answers" and have been searching for new questions and the rest of the answers in applied science and engineering practice ever since. I hope that this text will support the proposition that engineers and scientists engaged in remediation of coal-tar environmental problems are embarking on a quest for site-specific information to be gathered, evaluated, and tested on a ground of common knowledge. This book is therefore offered on the basis that our coal-tar environmental problems need to be solved and that the optimal solutions will come from application of the well-known concept of "best practice"—the benchmark of American environmental remediation for the past four decades.

The Gasometer
Alive, as was not Giotto's perfect circle,
Silent, yet teeming inwardly
With compressed life,
The Waldonbury gasometer takes the dawn,
It is not old like the crumbling Gothic arch,
But young, with that transcendent youth
Of vast mechanical things—
A dull magenta cowslip wrought of iron,
And ready to put out the gaseous leaves
of springtime.
Its perfume is the honest, absolute smell
Of selfless industry.
And by its windless pollination
A thousand flower-jets break into light
And strew with wan petals
The parlours of the uncontaminated.
Night and the dawn and daylight bloom
And pass,
And it is night again.
See! The Waldonbury Gasometer remains,
A tranquil condensation of a promise
In the dim entrails of a social conscience.

J. B. Morton, British Gasman on duty with the Royal Army,
France, 1944
(From Historic Gas Times*, Edinburgh, Courtesy of Dennis Unites,*
GEI Consultants, Colchester, Connecticut)

Coal, a natural hydrocarbon material, is at the center of all that this book has to present and to say. In this one material has come the heat of preservation and survival, the energy to power the industrialized world and the prospect that has driven invention. Coal has been the source of chemicals for all manner of industry, powered the railroads of international economic expansion, fueled the world's ships, gave us pharmaceuticals for our welfare, bright colors of textiles and printing, and those beyond our wildest imagination, and, in the special consideration of this book, the light with which the modern world came to read by. With this great largess of goodness came smog (coined of smoke and fog), acid rain (and the subsequent deterioration of our monuments to culture and history), silicosis (miner's black lung disease), and untold cases of all manner of cancers. Coal is indeed the jealous mistress.

Coal is a medium of exchange through the application of heat. When coal combusts in open flame fed with oxygen, it is reduced to the natural and incombustible geologic minerals and rock fragments that were the "dirt" of the swamp conceiving the black wonder. This "ash" largely is made up of tiny fragments of the minerals quartz and feldspar, together with a host of metallic sulfides, mainly as trace substances, except for sulfur, gathered in the death of the plant materials that flourished in the ancient swamps. Ash and sulfur never have been a willing participant of the gift of energy that coal has left to man. Countless armies of slaves and laborers have struggled to gather and remove and dispose of the ash, the sulfur compounds went up the chimneys and stacks of coal combustion and into the atmosphere, to be precipitated as particulates on the cityscape and the countryside alike.

In 1726, man learned to roast coal without the direct application of oxygen, thereby driving off gases containing the volatile content of coals and to receive a valuable fuel residue of nearly pure carbon, along with the incombustible mineral ash. Coke was the name of the fuel residue and it was a remarkable fuel for complete combustion later and at some place where the highest temperatures of the time could be had. The gases remained a curiosity for some 66 years until James Murdock, of Scotland, working as a self-educated mechanical engineer for Boulton & Watt of Smethwick, Soho District, Birmingham, England, put it to work. Murdock, a man known to us today for his prodigious energies, his inquiring mind, and an innovation to match both, collected that coal gas and ignited it at the end of a pipe for lighting his home at Redruth, Cornwall, in 1792. This was Murdock's off-hour inventive restlessness during the several years that he was the Boulton & Watt site engineer for installation and maintenance of the steam engines that powered the Cornish pumps that struggled to dewater the ever-deepening tin mines. Murdock, more the inventor than the entrepreneur, gave to his employers the planetary gear (becoming James Watt's patent) used as a patent circumvention to more effectively transfer the power of the company's steam engine and a gas-lit celebration of the short-lived Peace of Amiens (Seven Years' War with France). Here the Soho factory at Smethwick was lit by flares at its upper corners. The year was 1802.

Manufactured gas, coke, and their recovered coal-tar residual by-products was an industry essential to the Industrial Revolution, flourishing from 1812 to 1962. Literature relating to these industries is rich, complicated, and often elusive. Substantial technical references date from Murdock's plea for a royal charter (1809) to establish the world's first commercial gasworks (which was brought to actuality by Windsor [Winzler] in 1812) and Accum's 1815 British treatise, published the year before America's first gasworks was established in Baltimore, Maryland. Literally hundreds of technical books and thousands of individual papers have been published on all aspects of gas and its manufacture, use, and distribution, and on the nature of their residuals and unwanted wastes. Unfortunately for the 170-year active life of manufactured gas, the fate of gas-manufacturing wastes went the way of all other industrial wastes, unmanaged disposal beyond growing efforts to collect and distill the coal tars in the presence of local, then world markets. Today, only the most astute geological site investigation effort, combined with a detailed technical and operational chronology of an FMGP can lead to an accurate site and waste characterization. Such is the basis for effective remedial design and construction to mitigate the environmental threats represented by the on-site and migrated coal-tar wastes. This book has as its main goal the overall description of the historic technology of manufactured gas and coke and the fate of its toxic residual wastes, along with a guide to today's remediation technical literature. Considering my estimation of some 5000 individual FMGPs that are to be found in the United States, the thousands of factory and institutional gas producers, and the tens of thousands of producer gas engines of America's past factories, the remediation challenge will remain with us for decades. Expanded to the remainder of North America, Europe, and the main ports of world trade, and the problem of managing or otherwise dealing with FMGPs and coke works is immense.

NATURE OF TODAY'S ENVIRONMENTAL THREAT

FMGP and other coal-tar sites (including coke works) constitute one of the most challenging types of toxic waste sites in terms of characterization and remediation. Worldwide, the facilities date from 1802 (Birmingham), 1812 (London), and 1816 (Baltimore) to the present, with a handful of plants still on standby status. In the course of their incomplete combustion of coal to produce artificial gas for illumination, heating, cooking, and foundry, shops, and brickworks energy, and chemical by-product recovery, they produced many common hazardous wastes. Applicable coal-tar waste include the volatile organic compounds (VOCs) monocyclic aromatic hydrocarbons (MAHs—e.g., BTEX: benzene, toluene, ethylbenzene, and xylene), polyaromatic hydrocarbons (PAHs—18 major compounds, including the declared carcinogens benzo[a]anthracene, benzo[a]pyrene, benzo[B]fluoranthene, chrysene, and dibenzo[A,H]anthracene), semi-volatile organic compounds (SVOCs) and the tar acids (phenols and cresols), and a common list of inorganics such as ferrocyanides and heavy metals, the former generated in gas purification and the latter trapped as trace contaminants in gas purification wastes.

THE CHALLENGE OF SITE AND WASTE CHARACTERIZATION

Exactness of the chemistry of coal combustion, carbonization, and distillation has evaded scientists from the earliest days of coal's industrial utilization. Today, we know far less about this body of potential knowledge than we could be expected to know. Basic to this problem is that all of the physical conditions that surround the destructive use of coal exert great challenges toward effective environmental response toward mitigation of today's remaining toxic threats.

Starting with this perplexing array of physical and chemical variants, we tend to shrug off the details of coal-tar site chemistry as being unsolvable in terms of selection and design of remedy. Such should not be the case, for we should proceed like detectives and seek contrasting approximations of the character of waste, all tied to the major time-related process characteristics of each site, as affected by the unique natural geologic and hydrologic setting of each location. It has been my intent to examine each body of physical, chemical, technological, and chronologic evidence in order to develop rational pathways through the data that survive and that can be collected and analyzed.

This coal-to-energy technology spread widely toward the end of the nineteenth century and flourished also in the form of coke works, various by-product plants and distilleries, and literally tens of thousands of factory-dedicated gas producers and gas engines. Today's site owners and regulatory officials are seeking clear paths to transfer and/or reutilize such properties or to meet basic compliance in terms of dealing with environmental regulatory agencies. This book is meant to be a one-stop source of information for the entire process of site remediation.

TODAY'S SCIENTIFIC AND TECHNICAL QUEST FOR YESTERYEAR

Relatively speaking, there are no absolutes in consideration of coal-tar sites. The tars were mostly black; the evidence today comes in shades of gray. An allusion here is drawn with the world of communications, in which "white" is regarded as an ethical attempt to seek and present or portray the truth. In the world of communication "black," as a contrast to "white," is considered to represent untruths or possibly lies. "Gray" therefore occupies the often vast realm between truth and falsity. Gray is held to represent veiled or partial or poorly understood or misunderstood truths or either truth or falsity shaded by ignorance or deviousness to represent white or black.

In dealing with individual FMGPs and other coal-tar sites, it should be our aim to conduct our research, planning, and field data acquisition in the manner of a forensic investigation. Each possible element of the history and operation of the gas plant, coke works, or tar distillery should be developed through site and general research so that a plausible premise of its potential impact on environmental impact can be at least deduced to a high level of certainty in terms of possibilities. In this search for the "white" side of the character of coal-tar sites, I have taken advantage of the quoted words of historic gas and coal-tar practitioners. Let them help us to develop the intellectual minds of gas engineers and tradesmen of the last 200 years. Let them advise you of the possibilities and the probabilities that will ultimately determine the success of our remediation efforts.

These are the "leads" of the scientific detection that must follow in characterizing the site and its wastes. The forensic-like site investigation should operate on well-founded technical premises and then the field activities should be planned to encompass the actual or most likely truth of each line of evidence.

A well-intentioned coal-tar site and waste characterization should consider the following steps, presented in approximate rational order:

1. What are the elements of information that we can expect to find in the archives and the literature, as concerns this one site?
2. How is the site expected to have been operated in the sense of its affinity to the industry of manufactured gas and other coal-tar-related activities?
3. What could we expect to find in the way of evidence at the site?
   Consider the site to represent a source of technical archeological information.

4. Where will the evidence be located at and below the site?
   Conversely, we must know where not to look, on the basis on not encountering evidence, in the allocation of reasonable resources made available to seek the truth of the uncontrolled toxic waste site.
5. In what form will the specific evidence be found?
6. How will the evidence change or grade from its highest and best-recognized or most definitive form, to only a bare trace? Here we must consider the always-present question of *contaminant source*, as contrasted with *contaminant migration*.
7. We must know how to recognize the evidence once we have chosen the correct places for its search.
8. Once collected, the evidence must be properly recorded and preserved, a small bit as archival information for the remedial feasibility study, and the bulk submitted for controlled laboratory analysis.
9. Visual and observational evidence must then be assessed and correlated with the general historic technology of coal-tar activities and, as well, with the historic chronologic assessment of the site.
10. As the evidence is developed, so must it be assessed for its meaning, in the broader sense of coal-tar technologies and in the narrow sense of site history and the geologic and hydrologic controls over its fate and transport in the sense of its environmental impact of today and tomorrow.

Every action taken in planning and execution of site and waste characterization should be supportable by a simple explanation of the rationale driving the selection and nature of detail.

EFFORTS TO REMEDIATE COAL-TAR SITES

Attention to FMGPs varies widely between EPA regions and state environmental agencies. As in most enforcement cases, there has been an increased effort to seek FMGPs owned or previously operated by the more visible and financially solvent potential responsible parties (PRPs). To date, this has centered on the electric utility industry, which began to purchase their gas competitors in the early 1920s and completed most of the acquisitions as a result of introduction of long-distance natural gas pipelines beginning in 1930. More activity came with the Truman-era national antitrust breakups of the giant utility-holding companies, beginning in 1947.

Financial pressures represented by site and waste characterization and remediation of FMGPs are heavy burdens for today's utilities to bear and the entire prospect has been greeted with some degree of concern, bordering in some instances on alarm. The utilities believe that it is their right to pass as much of this current cost of doing business on to customers as rate surcharges. As controlled by state public utilities commissions, approval of rate surcharges for environmental restoration is a chancy endeavor. Such bodies generally will grant financial relief to the utilities only on the basis of definite budgets and schedules for completion.

OBJECTIVE OF THIS BOOK

I hold a firm conviction that the only way to adequately remediate an uncontrolled hazardous waste site is to employ a site and waste characterization effort commensurate with gathering sufficient data to accurately characterize both site and waste. From complete and accurate characterization comes reasoned feasibility deliberations and selection of remedy. Our gas plant, coke works, and other coal-tar remediation targets are almost all long out of operation and the essentials of their operational conditions are known, at best, only incompletely.

Nevertheless, the history and technologies of manufactured gas, coke, and by-products recovery are well known in general and there remain, for nearly all FMGPs and coal-tar sites, available information subject to historical research and careful and well-intentioned site exploration such that the essential elements of knowledge can be recovered for nearly all sites.

I have attempted to reconstruct the historical and technical framework of manufactured gas, coke, and coal by-product recovery to such a degree that actual answers are here available for most of the decisions that need to be made on the way through data collection and selection of remedy. It is never enough or sufficient to state that "we don't know" or "we don't have any historical data" and then go on to make more statements relating to the fact that a particular site does not need a sufficient site and waste characterization, or to conduct a flawed investigation and then make summary statements to the effect that the site does not present threats to people or to the environment. There are simply too many available avenues of data collection and interpretation to avoid flawed pursuit of the truth.

Statements and data arrayed here are made on the basis of facts that appear to be more or less immutable for "most" of various types of subject coal-tar sites. Readers should not hold these statements or facts to be immutable, but they are believed to be correct to the relative degree that they are offered for consideration of those persons working to characterize and remediate coal-tar sites. Take these statements and data as "probably applicable" for the aspects stated for a particular site, then exert a reasonable effort, taking the pathways provided and explained herein, and see if the relationships holds. See if you can improve on the correlation or, perhaps, be able, on the basis of good, established site-specific historic fact or field observation, test, or analysis, and refute that contention. In the end, we will all know that a reasonable and good effort has been made, in the good tradition of "the prudent man" and the standard of care for today's environmental remediation studies.

It is never sound or wise to call for nontreatment (no further action) closure of a coal-tar site on the basis of incomplete or flawed attempts to gather the wide variety of information that is available and which is the subject of this book.

It is equally important for all individuals interested in environmental improvement of gasworks sites to realize that alleged negative health effects should not be adhered to in the face of lacking scientific support for such a connection between the now-ancient coal-tar site and various diseases of the area for which some residents may suffer. Objections to short-term health concerns related to needs to open the surface of the site and to perform remedial actions should be tempered with the truly effective means now available for monitoring air emissions and the ways in which such emissions can be controlled from reaching both workers and residents. No one is served by walking away from yesterday's toxic caches without applying the investigative technical capabilities available today, and by leaving these wastes to further contaminate the environment for tomorrow's unsuspecting victims.

HATHEWAY'S LAWS OF COAL-TAR SITE REMEDIATION

As we unravel the complexities of a now-largely dead technology, each of us who take it as part of our professional practice must come to be familiar not only with its makeup, facts, and substance. Pursued to its desired result, today's study of yesterday's technology also brings us to awareness of theories that seem to hold and to generalities that seem to dominate our perceptions. I herewith impart my *laws of coal-tar site remediation* (compiled, January 1997).

1. If it looks like coal tar and smells like coal tar, it just about has to be coal tar.
2. Organic matter, especially coal and petroleum gas oils, consumed under conditions of pyrolysis (partial combustion) produces tar; no exceptions.
3. Never say "never" with respect to some facet of coal-tar activity. The many independent and dependent effects of feedstocks, equipment, and operating policies often brought about departures from what may be perceived to have been the norm.
4. Gas men were entrepreneurs and they obeyed the laws of economics, not those of today's ethics of environmental management.

5. Coal tar discovered in today's urban environment is likely to have one of two heritages:
   a. This is the site of a coal-tar-generating activity
   b. These are uncontrolled residuals and/or wastes of a nearby tar-generating activity
6. Most coal-tar residuals are dense nonaqueous-phase liquids (DNAPLs), which strongly obey the laws of gravity.
7. Just because DNAPLs are "nonaqueous" does not imply that they do not contaminate groundwater.
8. Unsalable coal-tar residuals did not just "go away," they were dumped at the nearest available place.
9. Wishful thinking does not make today's coal-tar residuals "go away."
10. In fact, coal-tar residuals do not ever "go away." They have lives that approach the scale of geologic time.
11. Lime and wood gas purification media seldom had any secondary value. These were valueless wastes that can be presumed to have been so identified at the time of their disposal
12. Process waters (gas liquors) of one sort or another were abundant at gasworks and other coal-tar sites, and that water generally was cheap and abundant; hence, much of it was used once-through and then discharged.
13. If there is now or ever was a topographic depression or drainage feature at or adjacent to the coal-tar site, there is a strong possibility that it was not overlooked by or escaped the imagination of yesterday's manager of coal-tar residuals.
14. Chemical equilibria of coal-tar wastes are not insured in the geologic environment, and especially not so in the environment of uncontrolled disposal of gasworks and associated plant wastes. Every day presents an opportunity for chemical imbalance to occur and to release possibly unexpected waste forms or homologues.
15. Utility-holding companies were profit oriented; just about any idea capable of increasing profit would be strongly considered.
16. You cannot adequately remediate a coal-tar site without adequate site and waste characterization.
17. Adequate site and waste characterization cannot be planned, budgeted, or conducted without an adequate historical chronologic assessment of the works and its known or potential wastes.
18. One tiny mind, fearful of the loss of a job or personal prestige, can wreak havoc to the concept of adequacy in environmental remediation of coal-tar sites.
19. Locations of coal-tar-generating components of gasworks, coke works, and other such sites must be field investigated and correctly sampled and analyzed in order that the purveyor of proposed remedial action be considered credible.
20. Unsubstantiated statements about fate and transport of coal-tar residuals are just that. An easy meal of food-for-thought for a fool.
21. Do not believe unsubstantiated statements about coal-tar conditions at a coal-tar site. Test the statement for the effects of personal interest, historic and technical credibility, and then ask for substantiation as it relates to the site.
22. Certain geologic environments are typified by their irregularities and anomalies; each one, gone undetected by site characterization, represents a potential pathway for contaminant transport to human receptors.
23. Do not believe unsubstantiated statements about the geologic character of subsurface portions of a coal-tar site that have not been adequately investigated by direct methods.
24. Responsible parties have serious obligations to their neighbors, the community, the environment, and to compliance with the intent of the law and of its supporting regulations. They should be supported as long as they are willing to adequately respond to the remediation task.

25. Responsible parties should not to be considered fountains of unending wealth.
26. Unremediated coal-tar sites are an undesirable legacy not only for our own direct progeny, but for the human race for all time.

Each of the "laws" is somewhere discussed in the text that follows, likely more than once each.

CONVENTIONS OF STYLE IN UNITS OF MEASURE

In selecting units of measure, I have respected the technologies of manufactured gas, coke, and coal-tar chemistry, as practiced in North America and Great Britain. Certainly, the bulk of the original technology developed in Europe and there, to a slightly greater degree, in Scotland, England, and Belgium. The French and then the Germans followed. By about 1840 the ideas were moving about, as published in scientific and technical journals of the day, then followed by the engineering-oriented professional society journals. It is my impression that the British wrote the most, followed by the Germans, and that everyone read what they had to say, especially the Americans and Canadians. It is unclear how much of what the North Americans wrote appeared in British and Continental journals or how much attention may have been paid to such literature.

Right around the American centennial (1876) there is strong evidence that Europe, in general, began to pay attention to what the North Americans had to say and that by 1890, Europeans were touring American industry to learn. Americans cannot ever be shorted for their voracious reading of the foreign technical literature because of the national language, mostly English. There was little secrecy in spreading this technology, for the comfort offered by patents generally held out the impression (largely false) that invention would serve the inventor, not so much the emulator. Perhaps the greatest technical problem confronting today's coal-tar site remediator is the striking variety and breadths of the technologies, feedstocks, and operating procedures that attended the manufacture of gas, coke, and recovery of their residuals.

This book attempts to gather, define, explain, and comment on the huge variety of historically related facts that must be considered in order to understand a single coal-tar site and therefore determine how to ethically, practically, accurately, and economically remediate these potentially dangerous sites. It is by choice that I have elected to keep and work with the English system of measurement throughout the first eight chapters that deal with the historic technologies of manufactured gas, coke, and tar residuals recovery. With the partial exception of temperature, these were the units by which the processes operated in North America and Great Britain, virtually throughout their entire lifetime. When it comes to the process of characterization of the abandoned coal-tar sites and their remediation, I change to the metric system, for this is the world in which we all work today.

WHAT THE BOOK DOES NOT ATTEMPT TO ACCOMPLISH

I unabashedly proclaim that remediation of coal-tar sites cannot be accomplished on the basis of elegant science or technology. Seldom is it possible to adequately consider, assimilate, or make rational use of numbers that stretch more than two digits to the right of the decimal point. This you will note dominates in the first part of this two-part book. Likewise, for the sake of ease in reference, concentrations of compounds (contaminants) are referenced in ppb (parts per billion), ppm (parts per million), ppt (parts per thousand), and percent rather than in micrograms per gram (μg/g), milligrams per gram, or grams/kg (g/kg). Furthermore, the negligible differences between these concentrations in fluids (as contaminated groundwater or surface water) or as fluids or solids in soil. The objectives of the book do not require dealing with concentrations of contaminants as vapors contained in vapor and so such notation as ppbv and ppmv are not presented.

My reasoning? An attempt to introduce such accuracy into an otherwise unequally available or assembled body of knowledge would be a disservice to the reader.

In these pages, you will find all the considerations and facts that I have been able to discern as representing the essentials of characterizing a site where coal-tar residuals have come to be leaked, deposited, or dumped. These are the factors that, if not considered, can turn a site remediation effort into something between a hoax and a calamity. Truly, coal-tar that exists on a site, but which, for one or more reasons, has not been expected, sought, discovered, or declared, creates a site that cannot be adequately remediated. A poorly remediated site can be worse than an unremediated site, as those who have come to depend on its mitigation will sorely be unserved, disappointed, or injured, with time.

What then is presented here is my best approximation of the absolute or relative truths about coal-tar sites. In the absence of no better or more accurate information, these data should form the basis for rational discovery, interpretation, analysis, evaluation, discussion, and selection and conduct of the remedy. Treat the contents as a starting point for your own site and waste characterization; use the contents to plan, test, and season your results.