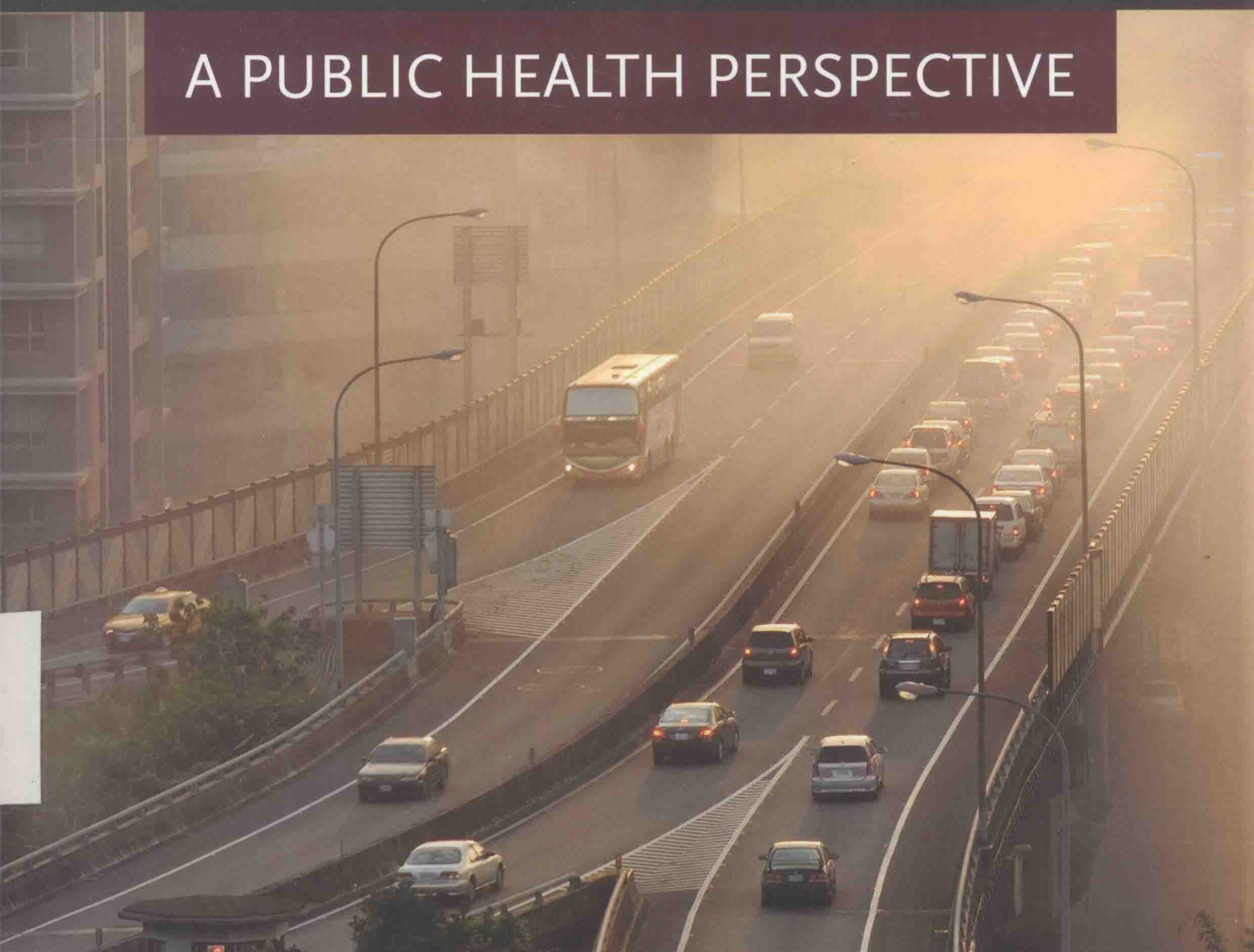
ROBERT F. PHALEN | ROBERT N. PHALEN

INTRODUCTION TO AIR POLLUTION SCIENCE

A PUBLIC HEALTH PERSPECTIVE



Introduction to Air Pollution Science

A Public Health Perspective

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Dedication

Figure FM–1 Paracelsus
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To Philippus Aurelus Theophrastus Bombastus von Hohenheim—Paracelsus (1493–1541), who probably made the single most important contribution to air pollution science by proclaiming:

> *"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison from a remedy."*

(Quote from Gallo, M. A. (2008) in Casarett and Doull's *Toxicology, The Basic Science of Poisons, 7th Edition,* Klaassen, C. D., Ed., McGraw–Hill Medical, New York.)

Preface

Air pollution science is both interesting and elegant because it integrates many disciplines. Responsibly managing air pollution requires the expertise and cooperation of a diverse array of specialists. Chemists, physicists, and engineers must have a working knowledge of public health, as well as the basic principles of toxicology, epidemiology, and the regulatory process. Also, public health professionals (including epidemiologists, toxicologists, and regulators) need to acquire a working knowledge of air pollution chemistry, physics, and engineering in order to be relevant and effective. In the interest of public health and welfare, it is no longer acceptable to pursue and promote one's own scientific discipline in isolation. A holistic approach is necessary, with the ultimate goal of making sound decisions that will best protect public health and the environment. To serve this end, this book covers essential traditional topics, as well as some that are new to air pollution textbooks. For example, full chapters are dedicated to risk assessment, toxicology, epidemiology, and ethics.

Traditional topics have been updated to address current issues in air pollution science (e.g., climate change). Individual chapters cover Sources and Emissions; Properties of Air Pollutants (Chemistry and Physics); Sampling and Analysis; Visibility, Climate, and the Ozone Layer; Regulation and Abatement; Human Exposures; Effects on Human Health; Toxicology; Epidemiology; Risk Assessment; and Ethics. The authors believe these are essential basic topics that students and professionals must appreciate in order to understand air pollution science. The chapters are scientifically current, and they introduce important basic concepts, online databases, and even some of the relevant peer-reviewed literature.

The authors have proven records in research and education in the air pollution sciences, and their formal scientific training, professional experience, and viewpoints are complementary. Their combined expertise and interests include air sampling, chemical analyses, aerosol science, industrial hygiene, inhalation toxicology, occupational health, biophysics, dermal toxicology, pollutant control technologies, applied ethics, and undergraduate, graduate, and post-graduate education. They have discussed, reviewed, and edited each other's contributions, and they have had many stimulating discussions and debates regarding the content presented in this text.

This textbook is necessary because it is: (1) motivated by a concern for public health and welfare, but also (2) current from a basic science viewpoint. As the Earth's population expands, air quality will worsen unless cleaner and/or more efficient technologies are developed for generating power, providing food, manufacturing goods, transporting goods, and enjoying life. On the other hand, many people throughout the world are still dealing with serious and very real health problems that are not associated with air pollution. These problems include poor nutrition, infectious disease, and natural disasters. Therefore, air pollution must be placed into a proper perspective within each society or community. Presenting this public health perspective is an important goal of this textbook. After all, the public must deal with all of the potential consequences of a regulatory action, not just the intended benefits.

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The authors must thank more people than they can name. First is Mrs. Leslie Kimura, who word-processed every chapter many times and served as our Administrative Assistant. Leslie's young daughter Kayla inspired us all with her patience and healthy scientific curiosity. She was also an invaluable companion to the authors' children and grandchildren, Joseph and Samuel.

Without the advice and help of Dr. Robert H. Friis, our role model as a textbook author, this project could neither have been begun nor completed. We are also appreciative of the guidance from Michael Brown, Maro Gartside, Rebekah Linga, Chloe Falivene, Grace Richards, Sophie Fleck, Teresa Reilly, Catie Heverling, and several other Jones & Bartlett Learning staff. Erica Martinetti, Robert N. Phalen, and Joshua Bracks expertly prepared several figures. The authors' families, Katherine Phalen, Michelle Phalen, and Nancy Phalen, tirelessly performed essential research, editing, and checking. Kathryn E. Terry, attorney at law and member of the California State Bar Committee on Ethics, offered expert suggestions on our ethics chapter. Rowe Yates contributed quiz questions. Dr. Loyda Mendez provided valuable advice.

The authors' children and grandchildren gave up valuable time with their parents and grandparents. They inspired us and helped us to relax during tense times by playing baseball with us. They deserve our most sincere appreciation.

Robert F. Phalen and Robert N. Phalen

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Foreword

Air, water, and earth sustain all living things, both plants and animals. They are the source of foodstuffs and energy critical to the well-being of human kind. Constant availability of oxygen within narrow concentration limits is essential for humans and all other mammalian organisms. Likewise, the constant availability of carbon dioxide within critical concentration limits is essential fuel for plants. The evolution of humankind has been strongly influenced by combustion, the interaction of carbonaceous materials and oxygen and the release of thermal energy. Primitive man learned to use fire to enhance the well-being of individuals and small communities of hunters and gatherers. This was soon followed by development of agricultural-based communities. The industrial revolution soon emerged with its strong dependence on the use of energy from available natural resources. That revolution was initially fueled by wood, then coal, and continues today with extensive use of coal, oil, natural gas, and to a lesser extent, uranium fuel for nuclear reactors as the primary energy sources. The availability of refined oil products, gasoline, diesel, and aviation fuel, has been the cornerstone of a transportation sector that has helped create a global economy. Increased agricultural productivity has been key to feeding a growing global population. Enhanced agricultural productivity has benefited from improved germ stocks, the use of petroleum product fueled equipment, and increased use of fertilizers. Nitrogen, extracted from the air, has played a critical role as a fertilizer.

Uses of carbon-based fuel stocks were initially very inefficient and resulted in significant emissions of a variety of gaseous and particulate pollutants primarily to air. Initially, the impacts were local, then observed regionally, and now are recognized as being of global concern. Air pollutants may directly impact the health of individuals and, in some cases, only be identified by studying very large populations. Other impacts on human populations may arise indirectly via contamination of water, soil, and plants. It is clear that the development of modern society has been dependent on the complex inter-relationships between air, water, earth, energy, and food production, and these, in turn, impact the health of the world's population. In both developed and developing countries, people are living longer on average than at any time in the history of human kind.

This text, by a father-son team, Robert F. and Robert N. Phalen, will be useful for undergraduate and graduate students and the lay public who want to better understand the multi-faceted nature of air pollution, its impact on society, and how the impacts can be mitigated. Their decades of experience as researchers studying the health effects of air pollution and as teachers have provided them with a valuable perspective often lacking in textbooks. They understand the scientific information being communicated. Equally as important, they understand the importance of communicating basic principles and using specific examples of the science to illustrate the principles.

Readers of the text will quickly identify a series of conceptual paradigms highly relevant to air quality that are recurring in the book. These include an emphasis on studying air pollution linkages from the sources of pollutants to the ambient air to the breathing zone of people to how inhaled materials are deposited and impact the respiratory tract and remote tissues. The individual chapters on

toxicological and epidemiological studies help the reader understand the strengths and weaknesses of each approach and how the resulting knowledge can be integrated. The Phalens wisely provide a chapter on the risk assessment process, which has emerged over the past half century as an approach to synthesizing information from multiple sources to understand human health hazards and risks. Every chapter provides not only coverage of science but, most importantly, places that science in the context of the global society in which we all live.

The senior Dr. Phalen received his undergraduate and early graduate education in Physics and then received his PhD in Radiation Biology and Biophysics. I had the pleasure of working with Robert F. Phalen at the Lovelace Inhalation Toxicology Research Institute (now the Lovelace Respiratory Research Institute), an institute whose successful research program was grounded on issue-resolving multi-disciplinary collaboration. At the University of California, Irvine, he has had an outstanding career as a research scientist and teacher. The junior Dr. Phalen received his undergraduate education in biology, gained experience as an Industrial Hygienist, and then received his PhD in Environmental Health. He has worked at the interface of applying science to resolving environmental and occupational health issues. The rich and varied experiences of the Phalens have taught them the importance of applying the skills of multiple disciplines in the physical, biological, and biomedical sciences, mathematics, information technology, engineering, the societal sciences, and philosophy to increase our knowledge base on air pollution and then use that knowledge to assist in resolving important societal issues. Students with an inquiring mind will identify many potential opportunities for developing a future career in one of the disciplines key to developing and using scientific knowledge of air pollution science.

Unlike many texts in the field, this book is not an encyclopedia of the knowledge of air pollution written from the perspective of multiple super specialists. Neither is this a doom and despair text with finger pointing to establish blame and advocate narrow viewpoints as to how society should move forward. This book exemplifies how science has an important role in helping human kind prosper and live healthy lives with thoughtful attention given to the quality of our air, water, and earth and the wise use of energy resources. Air quality is a crucial interface issue for the future of human kind. As William Shakespeare noted, "The golden age is before us and not behind us," and "What is past is prologue." This textbook will provide readers with an understanding of the past and current science of air pollution so they can be better contributors in the future.

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Robert N. Phalen, PhD, a Certified Industrial Hygienist, is an Assistant Professor of Environmental Health Sciences in the Health Science and Human Ecology Department at California State University, San Bernardino. In addition to his research on air quality, pesticides, sampling and analysis, and personal protective equipment, he teaches a variety of undergraduate courses and serves on administrative, education, and research committees (including the human subject's ethics committee).

The authors have approximately 150 combined scientific publications.

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