# *Fundamentals of Air Pollution*

FOURTH EDITION

Authors of Third Edition


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Dedicated to the four authors of the previous edition.
I am standing on the shoulders of giants.

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# Preventing and Controlling Air Pollution

# *Preface to the Third Edition*

The authors of this book include a chemist (Donald L. Fox), a meteorologist (D. Bruce Turner), and a mechanical engineer (Richard W. Boubel). This 1:1:1 ratio has some relevance in that it approximates the ratio of those professionally involved in the field of air pollution. In the environmental protection and management field, the experience of the recent past has been that physicists and electrical engineers have been most attracted to the radiation, nuclear, and noise areas; biologists and civil engineers to the aquatic and solid waste areas; chemists, meteorologists, and chemical and mechanical engineers to the area of air pollution and its control. These remarks are not intended to exclude all others from the party (or from this course). The control of air pollution requires the combined efforts of all the professions mentioned, in addition to the input of physicians, lawyers, and social scientists. However, the professional mix of the authors, and their expectation of a not-too-dissimilar mix of students using this book, forewarns the tenor of its contents and presentation.

Although this book consists of six parts and three authors, it is not to be considered six short books put together back-to-back to make one large one. By and large, the several parts are the work of more than one author. Obviously, the meteorologist member of the author team is principally responsible for the part of the book concerned with the meteorology of air pollution, the chemist author for the chapters on chemistry, and the engineer author for those on engineering. However, as you will see, no chapters are signed, and all authors

accept responsibility for the strengths and weaknesses of the chapters and for the book as a whole.

In the 20 years since publication of the first edition of *Fundamentals of Air Pollution* (1973), and the 9 years since the second edition (1984), the fundamentals have not changed. The basic physics, chemistry, and engineering are still the same, but there is now a greater in-depth understanding of their application to air pollution. This edition has been edited, revised, and updated to include the new technology available to air pollution practitioners. Its contents are also influenced to a great extent by the passage of the US Clean Air Act Amendments of 1990 (CAAA90). These amendments have changed the health and risk-based regulations of the US Clean Air Act to technology-driven regulations with extensive penalty provisions for noncompliance.

We have added more detailed discussion of areas that have been under intensive study during the past decade. There has been a similar need to add discussion of CAAA90 and its regulatory concepts, such as control of air toxics, indoor air pollution, pollution prevention, and trading and banking of emission rights. Ten more years of new data on air quality have required the updating of the tables and figures presenting these data.

We have expanded some subject areas, which previously were of concern to only a few scientists, but which have been popularized by the media to the point where they are common discussion subjects. These include "Global Warming," "The Ozone Hole," "Energy Conservation," "Renewable Resources," and "Quality of Life."

With each passing decade, more and more pollution sources of earlier decades become obsolete and are replaced by processes and equipment that produce less pollution. At the same time, population and the demand for products and services increase. Students must keep these concepts in mind as they study from this text, knowing that the world in which they will practice their profession will be different from the world today.

The viewpoint of this book is first that most of the students who elect to receive some training in air pollution will have previously taken courses in chemistry at the high school or university level, and that those few who have not would be well advised to defer the study of air pollution until they catch up on their chemistry.

The second point of view is that the engineering design of control systems for stationary and mobile sources requires a command of the principles of chemical and mechanical engineering beyond that which can be included in a one-volume textbook on air pollution. Before venturing into the field of engineering control of air pollution, a student should, as a minimum, master courses in internal combustion engines, power plant engineering, the unit processes of chemical engineering, engineering thermodynamics, and kinetics. However, this does not have to be accomplished before taking a course based on this book but can well be done simultaneously with or after doing so.

The third point of view is that *no one*, regardless of their professional background, should be in the field of air pollution control unless they sufficiently

understand the behavior of the atmosphere, which is the feature that differentiates *air* pollution from the other aspects of environmental protection and management. This requires a knowledge of some basic atmospheric chemistry in addition to some rather specialized air pollution meteorology. The viewpoint presented in the textbook is that very few students using it will have previously studied basic meteorology. It is hoped that exposure to air pollution meteorology at this stage will excite a handful of students to delve deeper into the subject. Therefore, a relatively large proportion of this book has been devoted to meteorology because of its projected importance to the student.

The authors have tried to maintain a universal point of view so that the material presented would be equally applicable in all the countries of the world. Although a deliberate attempt has been made to keep American provincialism out of the book, it has inevitably crept in through the exclusive use of English language references and suggested reading lists, and the preponderant use of American data for the examples, tables, and figures. The saving grace in this respect is that the principles of chemistry, meteorology, and engineering are universal.

As persons who have dedicated all or significant parts of their professional careers to the field of air pollution, the authors believe in its importance and relevance. We believe that as the world's population increases, it will become increasingly important to have an adequate number of well-trained professions engaged in air pollution control. If we did not believe this, it would have been pointless for us to have written this textbook.

We recognize that, in terms of short-term urgency, many nations and communities may rightly assign a lower priority to air pollution control than to problems of population, poverty, nutrition, housing, education, water supply, communicable disease control, civil rights, mental health, aging, or crime. Air pollution control is more likely to have a higher priority for a person or a community already reaping the benefits of society in the form of adequate income, food, housing, education, and health care than for persons who have not and may never reap these benefits.

However, in terms of long-term needs, nations and communities can ignore air pollution control only at their peril. A population can subsist, albeit poorly, with inadequate housing, schools, police, and care of the ill, insane, and aged; it can also subsist with a primitive water supply. The ultimate determinants for survival are its food and air supplies. Conversely, even were society to succeed in providing in a completely adequate manner all of its other needs, it would be of no avail if the result were an atmosphere so befouled as not to sustain life. The long-term objective of air pollution control is to allow the world's population to meet all its needs for energy, goods, and services without sullying its air supply.

# *Preface to the Fourth Edition*

In the Preface to the Third Edition of this book, Donald L. Fox, D. Bruce Turner, and Richard W. Boubel expressed the importance of a multidisciplinary approach to air pollution. I wholeheartedly agree. Nothing has changed in this regard, making it a daunting challenge to update the impressive work of these renowned experts (as well as the late Arthur C. Stern in previous editions). It was easier to add new material than to remove old material. A new edition is an optimization exercise. The book must not change so much that professors using it have to change the course structure so severely that it constitutes a completely new text. On the other hand, a text must be up to date in terms of current technologies and programs, as well as in addressing threats on the horizon.

Over a decade has passed since the publication of previous version. From a regulatory perspective, this is a very long time. By conventional measures, such as the National Ambient Air Quality Standards, the past decade has been very successful. But, science marches on. I recall that in the 1970s, detection in the parts per million (ppm) was impossible for most compounds. During the 1980s detection limits continued to decrease. Now, detections have improved to allow for measurements below parts per billion for many compounds. We have also witnessed sea changes in risk assessment and management. For example, the US Environmental Protection Agency laboratories were realigned to address risks, with separate laboratories to conduct research exposure, effects, risk characterization, and risk reduction.

Indeed, the previous authors were quite prescient in predicting the effects of the then newly amended Clean Air Act. The major changes started to kick in as the focus moved from technology-based approaches (best available and maximum achievable control technologies) to risk-based decision-making (residual risks remaining even after the required control technologies).

The fundamentals of the science underlying air pollution have not changed, but their applications and the appreciation of their impacts have. For example, I have endeavored to enhance the discussion and explanation of the physical and chemical processes at work, particularly those related to air toxics. This has been a tendency through all four editions. New technologies must be explained, better models and computational methods have become available, analytical procedures have evolved and improved, and acute and chronic effects have become better understood. All of these have enhanced the science and engineering knowledge available to practitioners, teachers, and students. And, the savvy of the lay public about air pollution has grown substantially during the previous decade.

I am indebted to my fellow scientists and engineers for their insights and comments on how to incorporate the new trends. I particularly want to note Alan Huber, who shared his work in atmospheric dispersion modeling, especially computational fluid dynamics. Others include Russ Bullock (mercury fate and transport), Paul Lioy and Panos Georgopoulos (modeling), Mark Wiesner (nanotechnology), John Kominsky and Mike Beard (asbestos), and Aarne Vesilind (history).

As in previous editions, my expectation is that the reader has received some formal background in chemistry. I agree with the previous authors that anyone interested in air pollution must have a solid grounding in chemistry and the physical sciences. Without it, there is no way of knowing whether a rule or policy is plausible. I have seen too many instances of "junk science" in environmental decision-making. Often, these are underlain with good intentions. But, so-called "advocacy" does not obviate the need for sound science. That said, with a bit of effort, much of this edition can be a useful tool to any audience who is motivated to understand the what, how and why of air pollution.

Another trend that I have hoped to capture is the comprehensiveness needed to address air quality. A problem need not occur if the processes leading to air pollution are approached from a life cycle or "green" perspective. This goes beyond pollution prevention and calls for an integrated and sustainable view. I have dedicated an entire chapter to this emergent environmental expectation.

The authors of the previous edition introduced discussions about some emerging continental and global threats to the atmosphere. Since then, the urgency of some has abated (e.g. acid rain and some threats to the ozone layer), some have increased in concern (e.g. global warming), and others have continued but the contaminants of concern have varied (long-range transport of persistent chemicals). The scientific credibility of arguments

for and against regulatory and other actions has been uneven. The best defense against bad policy decisions is a strong foundation in the physical sciences.

Let me rephrase that a bit more proactively and optimistically:

> My overall objective of this book is to give you, the reader, the ability to design and apply the tools needed to improve and sustain the quality of the air we breathe for many decades. These tools can only be trusted if they are thoroughly grounded in the *Fundamentals of Air Pollution.*
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