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potential expenditure of hundreds of millions of dollars to lower arsenic levels in drinking water would provide the greatest benefit, in terms of the available money for public health measures, when a number of other public health-related issues possibly are more pressing.

The subcommittee's chair, Vernon Ehlers (R-Mich.), said at the hearing, "Everyone knows that arsenic in large quantities is incredibly poisonous. But what we are examining here is the danger from arsenic in extremely minute amounts, equivalent to one teaspoon of arsenic in about 1.3 million gallons [4.92 million liters] of water. How much of a risk is the key question that brings us here today."

He added, "We have to use science to judge how we should allocate scarce resources to save and protect the most human lives."

An NRC report, "Arsenic in Drinking Water: 2001 Update," issued September 13, presents scientific data concerning arsenic toxicological risk and health effects. Robert Goyer, chair of the NRC's Subcommittee to Update the [Council's] 1999 Arsenic in Drinking Water Report—which produced the report—told the hearing that the 2001 update "confirmed the conclusions of the 1999 report; that chronic exposure to arsenic is associated with an increased incidence of bladder and lung cancer at arsenic concentrations below the current MCL [maximum contaminant level]."

Goyer said the new NRC report "suggests that the risks for bladder and lung cancer are greater than the risk estimates on which EPA based its January pending rule."

EPA's least protective standard for drinking water contaminants regulated by the Federal Safe Drinking Water Act indicates a risk of 1 person in 10,000 dying of cancer from a contaminant. However, Goyer said the NRC report indicates that "the theoretical lifetime excess risk for bladder and lung cancer combined is estimated to be approximately 1 in 1000 at 3 micrograms per liter."

Goyer also noted that a number of studies also indicate an association between non-cancer health outcomes for arsenic, such as hypertension and diabetes.

Differing Stances on NRC Report

Erik Olson, senior attorney with the Natural Resources Defense Council (NRDC), a nonprofit advocacy organization, said the association of certain levels of arsenic in drinking water with non-cancer outcomes adds to the risks, and simultaneously, to the benefits of lowering the acceptable level. He also disputed EPA's finding that the benefits of reducing arsenic levels to 3 ppb do not justify costs. Olson said that according to EPA's occurrence estimates and to risk estimates of the National Academy of Sciences for drinking water containing more than 3 ppb, "about 36 million Americans drink water every day that presents a cancer risk from arsenic that is ten times higher than what EPA considers acceptable."

However, Barbara Beck, an expert in toxicology and in health risk assessment for chemicals in the environment, said the NRC report was flawed for several technical reasons, including its assumption of linear responses to arsenic doses, rather than non-linear responses, which she said would result in lower risks. Beck, testifying on behalf of the American Wood Preservers Institute, the National Mining Association, and several other organizations with industrial interests, said the NRC report's conclusions "are based on assumptions that are based not on science, but on policy."

Help for Smaller Water Systems

John Scheltens, city engineer for Hot Springs, South Dakota, which has a population of 4,100, said that while public health concerns about arsenic levels may be a significant concern, he and many others in government and in public services provision for small communities need to balance limited financial resources. "If we truly believe arsenic is a public health [concern] at these levels, we need to deal with it at a national level," said Scheltens, who also testified on behalf of EPA's National Drinking Water Advisory Council (NDWAC).

On August 14, the NDWAC issued its recommendations on EPA's national cost estimates associated with regulating arsenic in drinking water at a lower-level standard. Among these recommendations are the initiation of a "sustainability fund" to help small communities meet such lower standards; the convening by NDWAC of a national working group to review EPA's methodology and assumptions for determining national affordability; and the consideration of lower-cost technologies and point-of-use devices in homes to meet arsenic standards.

NRDC's Olson also suggested that some of the \$1.7 billion in annual federal public water system assistance could be targeted to helping small water systems meet new arsenic standards.

Balancing Costs and Benefits

Rep. Ehlers, a physicist, said the arsenic issue is typical of difficult decisions the public faces in evaluating the costs and benefits associated with achieving various levels of environmental safety. He said that while there might be a good understanding of the health dangers of arsenic at various levels, and of the costs for meeting various standards for its presence in drinking water, questions loom about whether arsenic is a more serious public health issue than others, such as the risk of developing skin cancer from excessive exposure to the Sun.

"If we as a nation decide [to require reduced arsenic levels], can we save the most lives for \$1.7 billion by doing that?" he asked. "If we spent that money to get people to stop smoking, we would save far more lives; at that rate, you could bribe people to stop smoking." Ehlers added, "We should look at this [issue] in a holistic way. What can we do to maximize our money in clean water?"

For more information, visit the following Web sites: <http://www.nap.edu/catalog/10194.html> and <http://www.epa.gov/safewater/arsenic.html>.

Randy Showstack, Staff Writer

BOOK REVIEWS

Introduction to Atmospheric Chemistry

PAGE 490



PETER V. HOBBS

Cambridge Univ. Press, New York, 272 pp., ISBN 0-521-77800-X (paperback), 2000, \$24.95.

In thirty years of university teaching, Peter Hobbs of the Atmospheric Sciences Department at the University of Washington, has seen atmospheric chemistry grow from a relatively small branch of geosciences into one with which

every student of atmospheric sciences needs familiarity. Some students are captivated in their first course and make atmospheric chemistry a field of further study or a lifelong career. At the same time, courses of "global change" and emerging curricula in scientific policy require students from diverse backgrounds to develop sufficient knowledge to become well-informed policy-makers. A number of practicing atmospheric chemists are retrained on the job from other scientific backgrounds and need self-education in the basics of the field.

Hobbs reaches out to all these students in his new book, *Introduction to Atmospheric Chemistry*. He develops the topic from the

perspective of atmospheric physics, describing the atmospheres of planets including Earth in terms of physical principles as well as chemical composition and reactions/phenomena. The book begins with chapters on the origins of gases in the Earth's atmosphere, concepts of half-life and residence time, present-day chemical composition, and atmospheric radiation (absorption and scattering by gases and aerosols). Chapters 5 and 6 introduce the topics most closely connected with atmospheric chemical research: sources, sinks, photochemistry, transport, aerosol composition and properties. The last four chapters give topical introductions to four research issues in atmospheric chemistry: cloud and precipitation chemistry; biogeochemical cycles; air pollution; stratospheric chemistry.

Introduction to Atmospheric Chemistry is well-named. Each chapter is brief (8–25 pages) and truly introductory, eschewing detail and

long reference lists in favor of careful, clear explanations of basic concepts. Two appendices list the Periodic Table and SI Units.

The writing in *Introduction to Atmospheric Chemistry* is superb and, as one would expect from an experienced teacher, basic principles are reinforced by cross-referencing from one chapter to the next. A strength of the book is a series of worked exercises, suitably placed within each chapter. In addition, the book's first appendix is a set of problems for the student, with answers in a second appendix. Because of the exercises and other elements of careful pedagogy, Hobbs' book is likely to meet its objective in providing a sound basis for the beginning student, even one who is self-teaching. The historical notes enhance the quality of the book by showing how present-day concepts and practical applications derive from fundamental discoveries in radiation, thermodynamics, and chemical composition over the last 150 years.

There is a strong link between Hobbs' *Introduction to Atmospheric Chemistry* and his successful (and recently revised) *Introduction to Physical Chemistry for the Atmospheric Sciences*. The two books provide a one-year atmospheric chemistry curriculum for students with no previous physical chemistry coursework, a common situation for students entering the atmospheric sciences. The newer book depends heavily enough on the first book that students may feel obliged to buy both. Fortunately, they are small, light (in paperback), and inexpensive.

Hobbs' economy in references and avoidance of detail are at once the appeal of *Introduction to Atmospheric Chemistry* and a deficiency. The space and attention that the book gives to transmission of physical principles and problem-solving offer rigorous training for students of diverse backgrounds. Yet, some examples are dated and current topics in observations and modeling that

might inspire students to extra reading or research are absent. For example, in discussing the hydroxyl radical (chapter 5) and air pollution (section 7), there is no mention of recent measurements (e.g., OH, night-time oxidants, upper tropospheric peroxides) and the theoretical issues they raise. In the classroom, one would expect supplementary examples and readings to be provided with the textbook.

This book is highly recommended for the task of introducing this important subject to a range of students. Readers can communicate comments, corrections, and suggestions to the author at a Web site and perhaps welcome updates in the future.

Reviewer

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The Chemistry and Physics of Stratospheric Ozone

PAGE 490



ANDREW DESSLER

Academic Press, Calif., 209 pp., ISBN 0-122120-515, 2000, \$75.

Perhaps no other environmental issue has captured as much widespread public interest and concern as stratospheric ozone depletion due to man-made chlorofluorocarbons (CFCs). Increasing scientific understanding of the connections between CFCs and global-scale ozone changes, highlighted by observations of dramatic ozone loss in the Antarctic, has led to a landmark international treaty and subsequent treaty amendments. As outgrowths of these developments, stratospheric ozone depletion has found its way into science fiction fare and the term "ozone hole" has become part of the English lexicon.

The science behind stratospheric ozone is intensely interesting and the story of its development is as entertaining as any good mystery novel. By no means is the story—or the scientific understanding—complete. But we now know that a wide variety of physical and chemical processes combine to dictate the response of ozone to various natural and man-made perturbations. The key processes include transport of chemical species into, within, and out of the stratosphere, the chemical and photolytic decomposition of relatively long-lived gas-phase chemicals, and the kinetics of relatively fast reactions that interconvert short-lived chemical species and link them directly to ozone production and loss. In addition, much recent focus has been on aerosol surfaces that promote conversion of relatively

unreactive chemicals to more reactive forms and vice versa. The surfaces of interest include both ubiquitous sulfate-type aerosols, as well as fleeting polar stratospheric clouds composed of various mixtures of sulfuric acid, nitric acid, and water. The exploration of the microphysical details of the formation mechanisms and the precise chemical compositions of these aerosol particles has dominated the latest chapter of the ozone story.

Stratospheric ozone, with its mix of exciting science and powerful societal impact, is an obvious focus for an atmospheric science textbook. The typical atmospheric chemistry textbook covers an array of topics from tropospheric air pollution to stratospheric ozone to global climate change. *The Chemistry and Physics of Stratospheric Ozone*, however, is confined to stratospheric ozone and better integrates chemistry and dynamics topics into the central theme. Another difference is that Dessler targets the advanced undergraduate-level audience as opposed to the beginning undergraduate or graduate audiences addressed by most other textbooks on this topic. A particular strength of the book is its presentation of complex concepts in relatively simple terms, an attribute that makes the book inviting to both general atmospheric science students and those who wish to specialize in stratospheric science.

The book is organized into seven chapters. The first two introduce the general topic and important concepts needed for characterizing stratospheric ozone concentrations. The sections in chapter 2 dealing with time constants and atmospheric coordinate systems are especially good. Anyone interested in following the literature in this area needs to become familiar with terms like horizontal and potential vorticity coordinates as well as local and global lifetimes and Dessler's descriptions are both clear and concise. Chapters 3 and 4 provide fairly detailed descriptions of ozone chemistry, including a rather lengthy discourse

on the interactions within and among the chlorine, nitrogen, hydrogen, and bromine oxide chemical families. Chapter 5 presents a short overview of stratospheric dynamics. For an atmospheric chemist like myself, the treatment of dynamics is enlightening and the depth of discussion is adequate. However, atmospheric physicists might find the lack of detail regarding atmospheric waves and stratosphere-troposphere exchange to be a shortcoming.

Chapters 6 and 7 describe the response of stratospheric ozone to volcanic eruptions and CFCs in the polar regions. These real-life examples of ozone perturbations are the highlights of the book. Dessler's treatment of them is engaging and is well-linked to the fundamental concepts presented in the earlier chapters. A notable omission from the ozone perturbation examples, however, is aircraft and rocket exhaust effects. The latter topic serves not only to illustrate a number of valuable science lessons but, given that concern over supersonic aircraft preceded that over CFCs, it stands as an integral part of the ozone story.

The book does an excellent job of acquainting readers with the tools and terminology of current stratospheric ozone research in a highly intuitive fashion. Adding to its usefulness, the book contains a number of problems and "asides" that deal directly with common public misperceptions about ozone; for example, do CFCs really make it into the stratosphere? It should serve well as a college course supplement to one of the available general atmospheric science textbooks or as a concise reference in the stratospheric specialist's bookshelf.

Reviewer

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