ENVIRONMENTAL CHEMISTRY

NINTH EDITION

STANLEY E. MANAHAN

CRC Press
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The cover illustration depicts the pathway of solar energy captured by photosynthesis to convert atmospheric carbon dioxide to biomass that can be used as a feedstock for the thermochemical production of methane. This synthetic natural gas product is the cleanest burning of all the carbon-based fuels. Methane made by the biomass pathway is neutral with respect to the production of greenhouse gas carbon dioxide because any of that gas generated by combustion of biomass-based synthetic natural gas was removed from the atmosphere by photosynthesis in producing the biomass feedstock. Biomass-based synthetic fuel production and other sustainable energy technologies are discussed in detail in Chapter 19, "Sustainable Energy: The Key to Everything."

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Preface

Environmental Chemistry, ninth edition, maintains much the same organizational structure, level, and emphasis that have been developed through preceding editions, with updates in keeping with the emerging face of the dynamic science of environmental chemistry. Therefore, rather than entering into an immediate discussion of a specific environmental problem, such as stratospheric ozone depletion, the book systematically develops the concept of environmental chemistry so that, when specific pollution problems are discussed, the reader has the background to understand such problems. Chapters 1 and 2 have been significantly changed from the eighth edition to provide a better perspective on sustainability, environmental science as a whole, chemical fate and transport, cycles of matter, the nature of environmental chemistry, and green chemistry. The chapter on terrorism in the eighth edition has been removed, but specific aspects of this topic, such as the potential role of toxic substances in terrorist attacks, have been placed in other chapters. Because of the importance of energy to the environment and sustainability, an extensive new chapter on this topic has been added to the book. Separate chapters on basic chemistry and organic chemistry that were in the seventh and earlier editions have not been included, but may be obtained from the author or publisher in pdf format upon request.

The book views the environment as consisting of five spheres: (1) hydrosphere, (2) atmosphere, (3) geosphere, (4) biosphere, and (5) anthrosphere. It emphasizes the importance of the anthrosphere—that part of the environment made and operated by humans and their technologies. This environmental sphere has so much influence on the Earth and its environmental systems that, according to Nobel Prize winner Paul Crutzen, the Earth is leaving the Holocene epoch, throughout which humankind has existed on Earth until now and is entering the Anthropocene epoch, in which human influences, such as emissions of gases that significantly affect the warming and protective functions of the atmosphere, will have a dominant influence on conditions under which humankind exists on Earth. Since technology will in fact be used to attempt to support humankind on the planet, it is important that the anthrosphere be designed and operated in a manner that is compatible with sustainability and interacts constructively with the other environmental spheres. In this endeavor, environmental chemistry has a key role to play.

Environmental chemistry has evolved significantly since the first edition of *Environmental Chemistry* was published in 1972. (One interesting footnote to this evolution has been that with each new edition the calculation of the pH of ordinary rainwater has had to be revised because levels of atmospheric carbon dioxide had increased enough since each preceding edition to affect the result.) Whereas in the early 1970s environmental chemistry dealt largely with pollution and its effects, it now has a current emphasis upon sustainability. During the lifetime of the book, problems with organochlorine pesticides and detergent phosphates that cause water eutrophication have largely disappeared as the manufacture and sale of these substances have essentially ceased. When the book was first published, it was not known with certainty what happened to large quantities of carbon monoxide emitted to the atmosphere by automobiles; it was suspected that soil microorganisms metabolized this pollutant, but it is now known that the ubiquitous hydroxyl radical scavenges CO from the atmosphere. In 1972, the potential for stratospheric ozone depletion was just emerging as a major issue, but it was not known that refrigerant chlorofluorocarbons (freon compounds) were predominantly responsible for this threat. As the book progressed through various editions, the threat of these materials was revealed; the southern hemisphere springtime Antarctic ozone hole

was discovered, which grew ominously year by year; the manufacture of chlorofluorocarbons was banned as a consequence; and Molina, Rowland, and Crutzen shared a well-deserved Nobel Prize, the first ever in environmental chemistry, for their work in this field. The potential for greenhouse warming due to growing emissions of infrared-capturing carbon dioxide, methane, and other gases was shown to be a potentially huge problem for Earth and one that has not yet been resolved. In 1972, the terms green chemistry and industrial ecology had not yet been coined, but these disciplines emerged from the 1990s as crucial elements of environmental chemistry.

Chapter 1 provides an overview and background in environmental and sustainability science. The chapter is introduced with a brief discussion of the central issue of our time—energy, "From the Sun to Fossil Fuels and Back Again." This chapter introduces chemical fate and transport, environmental terrorism, and environmental forensics.

Chapter 2 defines environmental chemistry and green chemistry in some detail. The chapter discusses the important concept of cycles of matter. It introduces the anthrosphere, how it integrates with the other environmental spheres, and its effects on Earth. Components of the anthrosphere that influence the environment are discussed with emphasis on the all-important infrastructure that is part of the anthrosphere.

Chapters 3 through 8 deal with the hydrosphere. Chapter 3 introduces the special characteristics of water and the environmental chemistry of water. The remaining Chapters 4 through 8 discuss specific aspects of aquatic chemistry, aquatic biochemistry, and water sustainability and treatment.

Chapters 9 through 14 discuss atmospheric chemistry. Chapter 14 emphasizes the greatest success story of environmental chemistry to date—the study of ozone-depleting chlorofluorocarbons, which resulted in the first Nobel Prize being awarded in environmental chemistry as mentioned above. It also emphasizes the greenhouse effect, which may be the greatest of all threats to the global environment as we know it.

Chapters 15 and 16 deal with the geosphere, the latter chapter emphasizing soil and agricultural chemistry. Included in the discussion of agricultural chemistry is the important and controversial new area of transgenic crops. Another area discussed is conservation tillage, which makes limited use of herbicides to grow crops with minimum soil disturbance.

Chapter 17 goes into detail on the topic of green chemistry and the closely related area of industrial ecology. Chapter 18 discusses resources and sustainable materials.

Chapter 19, on energy, is new as a separate chapter in the ninth edition. Entitled "Sustainable Energy: The Key to Everything," it covers key topics on sustainable energy including conservation and renewable sources. The chapter ends with a proposed system of industrial ecology designed to produce methane from renewable biofuels and hydrogen generated from the electrolysis of water using renewable wind or solar energy.

The nature and environmental chemistry of hazardous wastes are covered in Chapter 20 and industrial ecology for waste minimization, utilization, and treatment in Chapter 21.

Chapters 22 and 23 cover the biosphere. Chapter 22 is an overview of biochemistry with emphasis on environmental aspects. Chapter 23 introduces and outlines the topic of toxicological chemistry. Chapter 24 discusses the toxicological chemistry of various classes of chemical substances.

Chapters 25 through 28 deal with environmental chemical analysis, including water, wastes, air, and xenobiotics in biological materials.

As noted above, two chapters on basic chemistry and organic chemistry that were present in the seventh and earlier editions have been removed from this edition for the sake of brevity. Readers who need this material can obtain files containing these chapters from the publisher or the author.

I welcome comments and questions from readers. I can be reached by e-mail at manahans@missouri.edu.

Stanley E. Manahan

Author

Stanley E. Manahan is professor emeritus of chemistry at the University of Missouri–Columbia, where he has been on the faculty since 1965. He received his AB in chemistry from Emporia State University in 1960 and his PhD in analytical chemistry from the University of Kansas in 1965.

Since 1968 his primary research and professional activities have been in environmental chemistry, toxicological chemistry, and waste treatment. His classic textbook, *Environmental Chemistry*, has been in print continuously in various editions since 1972 and is the longest standing title on this subject in the world. His other books are *Fundamentals of Environmental Chemistry,* 3rd ed. (Taylor & Francis/CRC Press, 2009), *Fundamentals of Sustainable Chemical Science* (Taylor & Francis/ CRC Press, 2009), *Environmental Science and Technology*, 2nd ed. (Taylor & Francis, 2006), *Green Chemistry and the Ten Commandments of Sustainability*, 2nd ed. (ChemChar Research, Inc, 2006), *Toxicological Chemistry and Biochemistry*, 3rd ed. (CRC Press/Lewis Publishers, 2001), *Industrial Ecology: Environmental Chemistry and Hazardous Waste* (CRC Press/Lewis Publishers, 1999), *Environmental Science and Technology* (CRC Press/ Lewis Publishers, 1997), *Hazardous Waste Chemistry, Toxicology and Treatment* (Lewis Publishers, 1992), *Quantitative Chemical Analysis* (Brooks/Cole, 1986), and *General Applied Chemistry*, 2nd ed. (Willard Grant Press, 1982).

Dr. Manahan has lectured on the topics of environmental chemistry, toxicological chemistry, waste treatment, and green chemistry throughout the United States as an American Chemical Society Local Section Tour Speaker and has presented plenary lectures on these topics in international meetings in Puerto Rico; the University of the Andes in Mérida, Venezuela; Hokkaido University in Japan; the National Autonomous University in Mexico City; France; and Italy. He was the recipient of the Year 2000 Award of the Environmental Chemistry Division of the Italian Chemical Society. His research specialty is gasification of hazardous wastes.

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