ENVIRONMENTAL POLLUTION

Laurent Hodges

Second Edition

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PREFACE

This book has been written to fill the need for a one-volume scientific discussion of environmental pollutants—their nature, their sources, their effects on people and animals and their surroundings, the circumstances in which they are significant, the methods by which they can be avoided or controlled, and the present state of environmental legislation affecting pollutants.

Environmental science, like other sciences, is constantly in flux—new pollutants are identified, new effects are discovered and old ones better understood, new laws are passed, old textbooks require revision. A knowledge of the material presented in this book, particularly the general biological, chemical, and physical principles that are introduced, will permit the reader to keep abreast of new developments and to place them in perspective.

The favorable reception accorded the first edition of this book has led to extensive updating and revision of the material. In addition to the use of more recent statistics and references and the revision of much of the text to incorporate new knowledge of environmental pollution, the following major changes have been made.

1. Each chapter concludes with a summary, providing the reader with a listing of the major themes of that chapter and some prominent examples of key points.
2. A list of questions has been added to each chapter. Some are problems having specific numerical answers; others are thought questions suitable for short essays or class discussion.
3. A number of suggested activities has been added to each chapter. These usually involve studying environmental problems in one's own community. Some involve a major effort that might require several participants.

4. The chapters dealing with energy have been extensively revised and augmented. Chapter 15 contains a much fuller discussion of the nuclear fuel cycle and of the advantages and disadvantages of nuclear power. The material in Chapter 16 has been rewritten to include at least short discussions of all the significant nonrenewable and renewable energy resources and their environmental effects.
5. A new Chapter 18 contains discussions of lead, mercury, cadmium, and other metal pollution, collecting and expanding material which in the first edition were scattered throughout the book. The material in the former Chapter 18 on pollution in foreign countries has been placed in several chapters of the second edition.

Several important features of the first edition have been retained, notably the following.

1. SI (metric) units are used throughout the book, although nonmetric quantities which may be more familiar to some readers are often given in parentheses at the same location in the text. Appendix 1 gives the conversion factors between important SI and nonmetric units and includes a list of the metric prefixes and their abbreviatons.
2. Scientific (exponential) notation is often used and is described in Appendix 1, which includes several questions dealing with this notation.
3. Appendix 2 provides lists of sources of further information that have been divided into three categories: (1) Recent books, some popular and some technical, on environmental science and specific areas such as air pollution. Together with the references at the end of the individual chapters, these provide a good start for the reader wishing to learn more about specific topics or to encounter other points of view. (2) Periodicals which deal wholly or partly with environmental pollution. (3) Addresses of sources of environmental information—government agencies, trade associations, environmental organizations, and other pertinent sources.

Many persons and organizations have helped me in preparing the two editions of this book. In particular I would like to thank

John Platt, whose talk on "What We Must Do" [*Science*, **166**:1115–1121 (1969)] was the original inspiration for the course from which this book evolved.

Dan Zaffarano and the Iowa State University Physics Department for their encouragement and support of my environmental teaching.

The Iowa State University Library.

John Millhone, Pat Cavanaugh, Rodson Riggs, and others associated with the Iowa Energy Policy Council for the opportunities which they provided me in learning and writing about energy, especially for Chapters 15 and 16.

The reviewers of the first and second editions, especially Robert Socolow.

All the scientists, government officials, and interested citizens whose work has contributed to our understanding of environmental pollution and has provided the basis for this book.

The staff at Holt, Rinehart and Winston, who have provided exceptional assistance in the editing and production of the two editions of this book, particularly Daniel Serebrakian and Sara Boyajian.

L.H.

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ENVIRONMENTAL POLLUTION

CHAPTER 1

INTRODUCTION

Environmental pollution is the unfavorable alteration of our surroundings, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution and abundances of organisms. These changes may affect humans directly or through their supplies of water and of agricultural and other biological products, their physical objects or possessions, or their opportunities for recreation and appreciation of nature.

Adapted from President's Science Advisory Committee, Environmental Pollution Panel, *Restoring the Quality of Our Environment.* Washington, D.C.: U.S. Government Printing Office, 1965

Pollutants that meet the criteria of this definition of environmental pollution are numerous: gases (such as sulfur dioxide and nitrogen oxides) and particulate matter (such as smoke particles, lead aerosols, and asbestos) in the atmosphere; pesticides and radioactive isotopes in the atmosphere and in waterways; sewage, organic chemicals, and phosphates in water; solid wastes on land; excessive heating ("thermal pollution") of rivers and lakes; and many others. Some of these pollutants are introduced into the environment naturally, others by human actions, and most in both ways. The major concern is with environmental pollution resulting wholly or largely as a by-product of human activities, because these can be controlled most readily.

The most important and controversial question left unanswered by this definition of pollution is, What constitutes an "unfavorable alteration"? Any human alteration of the environment probably has unfavorable effects, at least in the opinion of some people, and favorable effects in the opinion of others, such as those whose livelihood depends on an activity that produces pollution. The determination of the extent of the favorable versus unfavorable effects—or of benefits versus costs—is difficult just because it is ultimately subjective, even though objective data may be involved in the determination.

The developed nations of the world are likely to be more concerned about the unfavorable effects than those nations in which poverty and hunger are major unsolved problems. The unfavorable effects of pesticides and fertilizer runoff are likely to be of less concern in a country in which insufficient food production is leading to malnourishment and starvation or in which insect-borne diseases are major contributors to human morbidity and mortality than in a country with agricultural surpluses, relatively pure water supplies, and a strong public health program. Disagreements with regard to environmental concerns have been common at international meetings such as the United Nations Conferences on the Human Environment (1972) and on Population (1974). [1, 2]

Poverty, starvation, and pollution are not unrelated problems; they all reflect failure of the human race to design social and political institutions capable of properly assessing, controlling, and taking advantage of technological innovations. [3, 4] Despite the progress of the last few decades, serious problems of poverty and malnutrition exist in the United States. Although

progress has led to improvement in some environmental areas, it has brought about the aggravation of some existing environmental problems and the creation of new ones.

The rest of this chapter is devoted to examining certain characteristics of pollution: levels and movement of pollutants, effects of pollutants and how they can interact with one another, and relation of pollution to other technological hazards.

IMPORTANT CHARACTERISTICS OF POLLUTANTS

Natural and Artificial Pollution. Most pollutants that concern humans occur in nature, although chlorinated hydrocarbons (such as DDT) and certain short-lived radioactive isotopes are exceptions. In some cases, the environmental levels are largely due to natural sources; in others the levels are largely produced by human activities. Several examples of natural and artificial pollution are listed below.

Almost completely artificial
- Chlorinated hydrocarbons (DDT and others)
- Lead aerosols

Substantially artificial
- Oil on the oceans
- Phosphates in running waters

Substantial contributions from natural sources
- Hydrocarbons in the atmosphere
- Radiation
- Sulfur oxides in the atmosphere

Even when natural sources are more significant on a global scale, artificial pollutants (those produced by human actions) may be more significant in urban and industrial areas where the adverse effects of pollution are most severe. It is thus important to distinguish between large-scale production of pollutants and local production over a few tens or hundreds of square kilometers.

Concentrations of Pollutants. Concentrations of pollutants are often expressed by fractions. A concentration of one part per million (1 ppm) corresponds to one part pollutant per one million parts of the gas, liquid, or solid mixture in which the pollutant occurs. In a gas mixture the reference is generally to ppm by *volume*; in liquids and solids the reference is generally to ppm by *weight*. More recently it has become customary to express gaseous pollutants and particulate matter in the atmosphere in mass density units of micrograms per cubic meter ($\mu g/m^3$), and in this case it is necessary to specify the temperature (usually 0 or 25 °C) and pressure (usually 1 atmosphere—atm) at which the concentration is expressed. Table 1–1 lists some common fractional con-