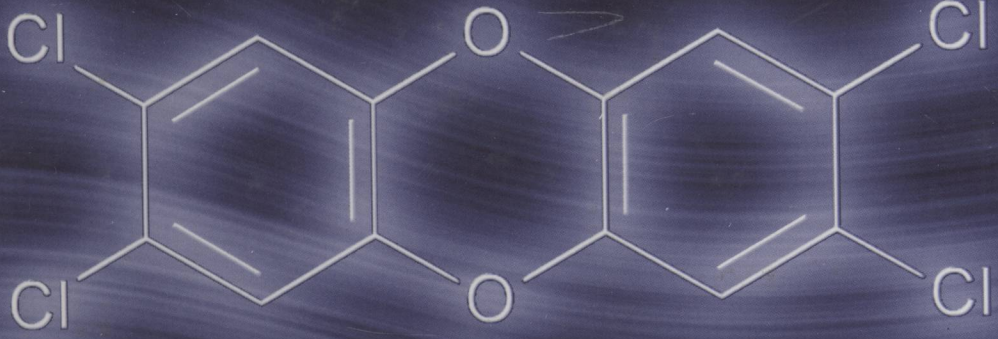
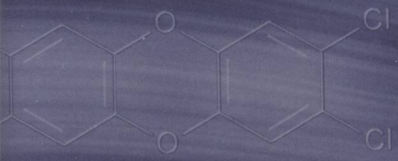
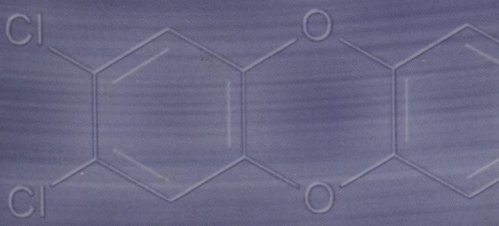
Second Edition

ORGANIC POLLUTANTS

An Ecotoxicological Perspective







C. H. Walker

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With contribution from Charles Tyler

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Preface to First Edition

This book is intended to be a companion volume to *Principles of Ecotoxicology*, first published in 1996 and now in its second edition. Both texts have grown out of teaching material used for the M.Sc. course, Ecotoxicology of Natural Populations, taught at Reading University between 1991 and 1997. At the time that both of these books were written, a strong driving force was the lack of suitable teaching texts in the respective areas. Although this shortcoming is beginning to be redressed in the wider field of ecotoxicology, with the recent appearance of some valuable new teaching texts, this is not evident in the more focused field of the ecotoxicology of organic pollutants viewed from a mechanistic biochemical point of view. Matters are further advanced in the field of medical toxicology, where there are now some very good teaching texts in biochemical toxicology.

Principles of Ecotoxicology deals in broad brush strokes with the whole field, giving due attention to the top-down approach—considering adverse changes at the levels of population, community, and ecosystem, and relating them to the effects of both organic and inorganic pollutants. The present text gives a much more detailed and focused account of major groups of organic pollutants, and adopts a bottom-up approach. The fate and effects of organic pollutants are seen from the point of view of the properties of the chemicals and their biochemical interactions. Particular attention is given to comparative metabolism and mechanism of toxic action, and these are related, where possible, to consequent ecological effects. Biomarker assays that provide measures of toxic action are given some prominence, because they have the potential to link the adverse effects of particular types of pollutant at the cellular level to consequent effects at the levels of population and above. In this way the top-down approach is complementary to the bottom-up approach; biomarker assays can provide evidence of causality when adverse ecological effects in the field are associated with measured levels of pollutants. Under field conditions, the discovery of a relationship between the level of a pollutant and an adverse effect upon a population is no proof of causality. Many other factors (including other pollutants not determined in the analysis) can have ecological effects, and these factors may happen to correlate with the concentrations of pollutants determined in ecotoxicological studies. The text will also address the question "To what extent can ecological effects be predicted from the chemical properties and the biochemistry of pollutants?," which is relevant to the utility, or otherwise, of the use of Quantitative Structure Activity Relationships (QSARs) of chemicals in ecotoxicology.

The investigation of the effects of chemicals upon the numbers and genetic composition of populations has inevitably been a long-term matter, the fruits of which are now becoming more evident with the passage of time. The emergence of resistant strains in response to the selective pressure of pesticides and other pollutants has given insights into the evolutionary process. The evolution of detoxifying enzymes such as the monooxygenases, which have cytochrome P450 at their active center, is believed to have occurred in herbivores and omnivores with their movement from

water to land. The development of detoxifying mechanisms to protect animals against plant toxins is a feature of plant-animal "warfare," and is mirrored in the resistance mechanisms developed by vertebrates against pesticides. In the present text, the ecological effects of organic pollutants are seen against the background of the evolutionary history of chemical warfare.

The text is divided into three parts. The first deals with the basic principles underlying the environmental behavior and effects of organic pollutants; the second describes the properties and ecotoxicology of major pollutants in reasonable detail; the last discusses some issues that arise after consideration of the material in the second part of the text, and looks at future prospects. The groups of compounds represented in the second part of the book are all regarded as pollutants rather than simply contaminants, because they have the potential to cause adverse biological effects at realistic environmental levels. In most cases these effects have been well documented under environmental conditions. The term *adverse effects* includes harmful effects upon individual organisms, as well as effects at the level of population and above.

The layout of Chapters 5 through 12, which constitute Part 2, follows the structure of the text as far as possible. Where there is sufficient evidence to do so, the presentations for individual groups of pollutants are arranged as follows:

Layout in present text	**Book divisions in *Principles of Ecotoxicology***
1. Chemical properties	1. Pollutants and Their Fate in Ecosystems
2. Metabolism	
3. Environmental Fate	
4. Toxicity	2. Effects of Pollutants on Individual Organisms
5. Ecological effects	3. Effects on Populations and Communities

C. H. Walker
Colyton

Preface to Second Edition

The first edition of this text was written as a companion volume to *Principles of Ecotoxicology*, first published in 1996 and now in its third edition. Both books grew out of an M.Sc. course, Ecotoxicology of Natural Populations, taught at Reading University between 1991 and 1997. The aim of the first edition was to deal in greater depth and detail with mechanistic aspects of ecotoxicology than had been appropriate for the broad introduction to the subject given in *Principles of Ecotoxicology*.

This second edition has retained the overall structure of the original text and is intended to be a companion volume for the third edition of *Principles of Ecotoxicology*. In producing it there have been two major aims. First, the entire text has been updated to take into account recent developments in the field. Secondly, the third part of the text has been considerably expanded: this section deals with the problems of complex pollution and the exploitation of recent scientific and technological advances to investigate them. In the first edition, the main focus was upon the environmental effects caused by major groups of pollutants, which were described in the second part of the text. More complex pollution patterns were dealt with only briefly, in the third part of the text. Here, two new chapters have been added to strengthen Part 3 of the text, "Endocrine-Disrupting Chemicals and Their Environmental Impacts" and "Neurotoxicity and Behavioral Effects," as well as expanding Chapters 13 and 17.

Professor Charles Tyler has made an important contribution to this text—first by writing, in collaboration with his colleague R. W. Goodhead, a new chapter on endocrine disruptors, which greatly strengthens the third part of this book, but also by giving much valuable discussion and advice on other aspects of the subject relevant to the present book. He is head of a research group at the University of Exeter that investigates endocrine disruption in fish and is particularly well qualified to make this contribution because, as well as being at the cutting edge of this area of research, he runs a course in ecotoxicology for final year undergraduates at the University of Exeter. I am also very grateful to my former colleague at Reading University, Dr. Richard Sibly, for much valuable discussion on population biology and the employment of new techniques, including those of genomics, in studies on the population effects of pesticides and other pollutants.

It is hoped that this text will prove useful to final-year undergraduates, higher degree students, and to researchers in the field of ecotoxicology.

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Acknowledgments in First Edition

Many people have contributed in various ways to this book, and it is not feasible in limited space to mention them all. Over a period of nearly 40 years, colleagues at Monks Wood have given valuable advice on a variety of subjects. At Reading, colleagues and students have given much good advice, critical discussion, and encouragement over many years. Working visits to the research group of Prof. Franz Oesch in the Pharmacology Institute at the University of Mainz were stimulating and productive. Advanced courses such as the ecotoxicology course run at Ecomare, Texel, the Netherlands, by the European Environmental Research Organisation (Prof. and Mrs. Koeman), and the Summer School on Multidisciplinary Approaches in Environmental Toxicology at the University of Siena, Italy (Prof. Renzoni), did much to advance knowledge of the subject—not least for those who were fortunate enough to be invited to contribute! To all of these, grateful thanks are due.

David Peakall has been a continuing source of good advice and critical comment throughout the writing of this book—not least for compensating for some of the inadequacies of my computer system! Richard Sibly and Steve Hopkin continued to give advice and encouragement after completion of *Principles of Ecotoxicology*. I have benefited from the expert knowledge of the following in the stated areas: Gerry Brooks (organochlorine insecticides), Martin Johnson (organophosphorous insecticides), Ian Newton (ecology of raptors), David Livingstone and Peter Donkin (marine pollution), Frank Moriarty (bioaccumulation and kinetic models), Ken Hassall (biochemistry of herbicides), Mike Depledge (biomarkers), and Demetris Savva (DNA technology). My gratitude to all of them.

Last but not least, I am grateful to all the research students and postdoctoral research workers at Reading who have contributed in so many ways to the production of this text.

Contents

Part 1

Basic Principles

The first part of the book will deal with the basic principles that determine the environmental distribution and toxic effects of organic pollutants in order to set the stage for Part 2, which describes the properties and behavior of major groups of compounds that fall into this category. The first chapter puts this issue into evolutionary perspective. From a toxicological point of view, organisms have been exposed to toxic xenobiotics for much of the evolutionary history of this planet—much longer than they have encountered human-made organic pollutants, which are the main subject of this book. Indeed, many such compounds have functioned as chemical weapons of both defense and attack, and animals have been found to possess detoxication systems for them, which also work against products of the chemical industry to which they could have had no previous exposure. Also, natural products with "biological activity" have often been used as models in the development of new pesticides and drugs.

Following this introduction, the next three chapters will describe the principles and processes that determine the fate and behavior of organic pollutants in the natural environment. Throughout, emphasis will be given to the importance of the physical, chemical, and biological properties of the compounds themselves in determining their fate and behavior. Chapter 2 is concerned with the factors that determine the distribution and toxicity of these compounds in individual organisms. Chapter 3 will describe the factors that determine the distribution of chemicals through the major compartments of the gross environment and attempts to develop descriptive and predictive models for this. Chapter 4 will focus on distribution and effects in communities and ecosystems.