MULTISPECIES TOXICITY TESTING

Edited by
John Cairns, Jr.

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Dedication

This volume is dedicated to W. B. Hart and S. H. Jenkins.

W. B. Hart was the senior author of the first toxicity test to be formally accepted as a standard method by the American Society for Testing and Materials. The original method was published by the Atlantic Refining Company in 1945 and subsequently adopted by the organization now called the Water Pollution Control Federation and then later formally accepted by the American Society for Testing and Materials. More tests have probably been carried out using this procedure or modifications of it than any other toxicity test using aquatic organisms. W. B. Hart also had the vision to see that laboratory toxicity tests with single species might not be enough to estimate the hazard to natural systems with precision. Therefore, he urged Ruth Patrick in 1947 to form the now famous Limnology Department of the Academy of Natural Sciences whose river survey teams studied literally hundreds of rivers throughout the United States and the world. Hart helped Ruth Patrick acquire funding from the Commonwealth of Pennsylvania to launch a major river survey investigation in 1948 involving a team approach. His advice to Ruth Patrick that a diversity of types of evidence was required to make an estimate on environmental harm has proven to be exceptionally sound, and the need to use both laboratory and field evidence in the process of risk analysis is widely accepted today.

It is also appropriate to honor S. H. Jenkins who for many years was Executive Editor of *Water Research*, the major publication of the International Association on Water Pollution Research and Control. Sam Jenkins was a firm believer in the value of biological and ecological information in determining water quality and the effects of pollutants on aquatic ecosystems. He was an early and enthusiastic supporter of the concept of biological monitoring and also believed in a close working relationship among engineers, chemists, and biologists. At an age when most people had long since retired, Sam not only participated in, but had a zest for, professional activities. At a meeting in Copenhagen, he took a manuscript I had just completed, read it during the conference, and returned it in a few hours with a number of suggestions and pointed questions. The manuscript was markedly improved as a consequence of his kindness and thoroughness. On the day he died, Sam

worked with enthusiasm and was planning a professional trip abroad the next day. He was a valuable professional to the very end!

It is often said, quite accurately, that professionals "stand" on the shoulders of those who preceded them. Therefore, it seems appropriate that we occasionally acknowledge their help!

Introduction to the SETAC Special Publications Series

The SETAC Special Publications series was established by the Society of Environmental Toxicology and Chemistry to provide in-depth reviews and critical appraisals on scientific subjects relevant to understanding the impacts of chemicals and technology on the environment. The series consists of single and multiple authored/edited books on topics selected by the Board of Directors for their importance, timeliness, need for updating, and their contribution to multidisciplinary approaches to solving environmental problems. The diversity and breadth of subjects covered in this series will reflect the wide range of disciplines encompassed by environmental toxicology, environmental chemistry, and hazard assessment. Despite this diversity, the goals of these volumes will be similar; they are to present the reader with authoritative coverage of the literature, paradigms, methodologies, controversies, research needs, and new developments specific to the featured topics. All books in the series are peer reviewed for SETAC by acknowledged experts.

The SETAC Special Publications will be useful to environmental scientists in research, research management, chemical manufacturing, regulation, and education, as well as to students considering careers in these areas, for keeping abreast of recent developments in familiar areas and for rapid introduction to principles and approaches in new subject areas.

Multispecies Toxicity Testing, the first volume to be published in this series, serves the aims of the series by synthesizing information and presenting a perspective on an emerging, controversial, and much needed methodology for predicting hazards to ecosystems from potentially toxic chemicals and other environmental stresses.

We wish to thank Ms. Maurine Lee for editorial assistance during peer review, Ms. Beverly Howard for designing the cover format for the series and Mr. Thomas Anthony for assistance in production of this volume.

Series Editors

C. H. Ward, Rice University
Barbara T. Walton, Oak Ridge National Laboratory

Preface

The symposium on multispecies toxicity testing was jointly sponsored by the Ecological Society of America (ESA) and the Society for Environmental Toxicology and Chemistry (SETAC). Selection of participants and subject matter was the responsibility of the editor, who had assistance from members of both societies. The symposium was held at Virginia Polytechnic Institute and State University May 15–18, 1983. Fortunately, some participants were able to obtain travel funding from their home institutions, although this was never made a precondition of any invitation.

The Mobil Foundation, Inc. and the Procter & Gamble Company generously provided funds that paid for expenses of all participants during the symposium itself and the transportation costs of a substantial number of participants as well. SETAC accepted the responsibility for sponsoring the publication of the symposium since the organization had arrangements with Pergamon Press to publish both their journal and the proceedings of workshops, conferences, and symposia. SETAC's editorial committee was responsible for selecting reviewers and carrying out the review process as well as for making final arrangements with the publisher. Sponsorship of the symposium indicated that both societies were interested in providing a forum for exchanging ideas relative to the merits and limitations of multispecies toxicity testing, which is now not commonly used in predicting the hazard of chemicals and other stresses to ecosystems. A major effort was made to include a diversity of viewpoints on this question. Neither society endorses the opinions and viewpoints expressed in this volume.

The purpose of this symposium was not to espouse a particular position but rather to provide both professional and nonprofessional readers with a diversity of opinions and viewpoints that will enable them to form an opinion. Some participants were specifically assigned the responsibility of identifying areas of agreement as well as areas of disagreement together with steps that might be undertaken to clarify some of the problems that could not be resolved. Because little scientific evidence is now available, this volume should be regarded as a preliminary examination of an important problem that deserves much more attention than it has received in the past.

Acknowledgments

Travel expenses for a number of the participants were provided by the Mobil Foundation, Inc. and the Procter & Gamble Company. Housing, meals, and other conference expenses were paid for all participants with these funds as were other incidental expenses associated with holding a symposium and publishing the proceedings. I am deeply indebted to these foundations for their financial support—without them this symposium could not have been held. I am also indebted to both the Ecological Society of America and the Society for Environmental Toxicology and Chemistry for sponsoring this symposium. The staff of the Donaldson Brown Continuing Education Center on the Virginia Polytechnic Institute and State University campus was helpful in a variety of ways in preparing for and holding the symposium. The many organizational and editorial duties rendered by Darla Donald during the planning of the symposium and the publication of this volume are gratefully acknowledged.

Introduction

A multispecies toxicity test may be defined most simply as any test at a level of biological organization higher than a single species. There is a clear implication that toxicological effects on lethality, growth, reproductive success, behavior, and a variety of other attributes of single species should not be used as end points because these are often most effectively carried out in single species tests. However, there are occasions when gathering single species data from multispecies toxicity tests is perfectly appropriate. Parameters studied in multispecies toxicity tests should primarily be those that cannot be carried out in single species tests, that is, predation, competitive interactions, rate of detritus processing or energy flow, nutrient spiraling, and a variety of other parameters that require more than a single species for adequate determination.

This book should not be interpreted as a criticism of single species toxicity testing. For the record, single species tests are essential to evaluation of hazard caused by chemicals introduced into the environment and a variety of other stresses. Any modern ecology text will abundantly document that there are many important attributes of complex biological systems that can only be adequately assessed by examining levels of biological organization higher than single species. This statement is so well established that it would be considered platitudinous to any assemblage of professional ecologists. The components, processes, and function of natural systems assumed to be protected by single-species toxicity tests are rarely explicitly identified as such and this is a source of confusion and misunderstanding. If we are merely endeavoring to protect certain species that are important to the general public from direct injury from waste discharges and other stresses, single species toxicity tests are then probably adequate if validated in natural systems. If, however, the assumption is made that single species toxicity tests also protect all the key attributes of complex ecological systems, there is not sufficient evidence to support this assumption (National Research Council, 1981; Cairns, 1980, 1983). It is conceivable that the most sensitive of the single species toxicity test results used with a sound application factor will inevitably protect the important attributes of complex ecological systems. The scientific evidence for this hypothesis is not persuasive. In addition, there are indications that more evidence than single species tests is required by law. In 1976, the National Resources Defense

Council and other environmental groups won a class action suit against the administrator of the U.S. Environmental Protection Agency (EPA) for noncompliance with Section 304 of Public Law 94/500. This section charged the administrator with developing and publishing water quality criteria that accurately reflected the latest scientific knowledge on the kinds and effects of compounds that may be deleterious to biological communities and their component species. One of the main purposes of the Toxic Substances Control Act (TSCA) is to establish a procedure for estimating the hazard to human health and the environment before widespread use of a chemical occurs. Most ecologists would question the scientific justification for assuming that biological communities and the environment are protected by single species toxicity tests. Unfortunately, ecologists, as a profession, have not formally identified those characteristics of communities, ecosystems, or the environment that regulatory agencies should protect. By formal identification, I mean a pronouncement based on a consensus of the membership or a vote of the majority that a particular characteristic (or series of characteristics) is the most important factor to protect. This information should be published in either the professional society's publication or by one of the organizations specifically dedicated to this particular practice, such as the American Society for Testing and Materials. If professional ecologists are unable to identify key measurements to be made and produce standard methods for making these measurements, they should not denounce the practical use of single species toxicity tests.

Defenders of the sole use of single species toxicity tests for protecting the environment maintain that the general public only wants protection insured for particular species that they consider especially valuable, particularly those valuable in sport fishing or commercially. There is to my knowledge no poll that defines with precision the feelings of the general public on this particular point. However, the law seems to be clear because more than one important law exists that specifies protection of the environment, not commercially valuable species. In addition, there is compelling evidence that members of the Sierra Club, the Audubon Society, Trout Unlimited, The Wilderness Society, and a substantial number of other organizations clearly understand that ecosystems are more than a miscellaneous collection of species and have important attributes that transcend the attributes of single species. Furthermore, there is circumstantial evidence that the general public understands this as well. For example, Study No. 822033, *A Survey of American Attitudes Toward Water Pollution*, undertaken in 1982 by Louis Harris and Associates, Inc. for the Natural Resources Council of America, Washington, D.C., had a section on wetlands protection. The pollsters reported that among the respondents, 83% said that it is "very important" to "keep the remaining wetlands free from further destruction," with 69% wanting federal standards

for preserving wetlands to be made "more strict" and 22% wanting them to be kept as they are. This appears to be persuasive evidence of public realization of ecosystems as systems rather than mere assemblages of species.

It seems there is truly a need to determine the role of multispecies toxicity tests in the overall process of hazard evaluation, that a significant segment of the general public is aware of the need to protect attributes of higher levels of biological organization than single species, and that the rest of the public can be educated to this need.

There is no question that the magnitude of the problem is so great that a single symposium, such as the one that resulted in this book, can only begin to address all of the components. However, it is my hope that the situation will be better defined as a result of this one. A symposium can assist in defining the problem so that a strategy can be developed for addressing the major needs and for insuring technology transfer when appropriate. A list of the aspects discussed herein follows, not necessarily in order of importance:

1. The type of scientific evidence industry expects from scientists before making a major commitment to multispecies toxicity testing is discussed. Industrial decision makers are not yet sufficiently persuaded about the utility of multispecies toxicity tests to make a major commitment to this testing. Some of the types of evidence and events necessary to elicit industry's commitment will be discussed.
2. There are still some scientific problems with multispecies tests that must be addressed before one would be justified in expecting a significant industrial investment in this area.
3. Any major shift in regulatory stance, such as from major reliance on single-species toxicity tests to include multispecies toxicity tests, would require significant adjustments in priorities.
4. There is clearly a wide gap between the qualities that professional ecologists feel need protection and those now being protected. Perhaps by stating the industrial, regulatory, and ecological positions on these matters some compromise can be reached.
5. A series of case histories is used to address a number of important areas: (a) responses unique to multispecies toxicity test systems useful to industry; (b) the correspondence of laboratory and field results with macroorganisms; (c) the use of multispecies test systems in salt water; (d) structural parameters for terrestrial systems; (e) the European view on multispecies toxicity tests; (f) a description of a presently operational multispecies toxicity system; (g) cost/benefit analyses of multispecies toxicity testing systems; (h) correspondence of laboratory and field results of multispecies toxicity test systems using microorganisms; (i) the problems of developing a "round-robin" procedure for determining the ability of different

laboratories to use multispecies toxicity tests; and last (j) the replicability of multispecies toxicity test systems.

A final chapter deals with those points of consensus, if any, and the major points of disagreement that need further resolution, and presents the degree of utility of multispecies tests.

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Contents

Chapter 1

Multispecies Toxicity Tests in the Safety Assessment of Chemicals: Necessity or Curiosity?

Gordon Loewengart and Alan W. Maki

INTRODUCTION

Considering the proposal to use multispecies toxicity tests in the hazard assessment of chemicals leads to a number of technical and logistical questions: What are the kinds of questions that administrators and business managers in companies are likely to ask when tests beyond single species toxicity tests are proposed? What needs to be accomplished to persuade decision makers within industry to incorporate multispecies, community, and ecosystem tests into hazard assessment programs? And with respect to ecologists, what must they do to make multispecies tests more attractive?

Specifically, within the context of the interrelated systems and conditions that exist in our contemporary regulatory and industrial environment, the objectives of this chapter will be to: (a) present our perspective of what industry needs from "applied ecology" relevant to both single and multispecies testing programs; (b) compare the benefits and limitations of single and multispecies tests; and (c) propose a place where multispecies tests can be used in hazard assessment schemes.

Before those questions are addressed, however, it is important to put them in the framework of the hazard assessment strategy employed in the corporate health and environmental safety management systems of most large companies.