# SURVIVAL IN TOXIC ENVIRONMENTS

Edited by

*M. A. Q. KHAN*

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# FOREWORD

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Ecologists and some governmental and private planners have long been aware of the global nature of our environment and the limits of some of our precious environmental resources. The recent shortage of one of these resources, petroleum, has demonstrated that even the most viable national economies and comfortable lifestyles are still subject to the availability of those resources.

It is appropriate that man, through his technology, be recognized as a major force for change on this planet. Because of his great capacity to control and modify habitat, man can, for better or worse, truly change environment. Certainly we must recognize that this capacity has established man as one of the most successful species on this planet; however, such success has almost of necessity involved an exploitative and wasteful attitude towards our limited resources. Uncontrolled population growth, non-recycling of non-renewable resources, contamination of air, water and food resources through inadequate waste disposal techniques are but symptoms of that attitude.

Professor Eugene Odum has drawn the analogy between living systems and cybernetic systems. The latter systems are composed of interdependent parts that function together and exist in two states, a transient state and a steady state. The transient state is equated with the youthful state, a state of rapid growth in which growth itself is necessary for the survival of the system. This transient state with its positive feedback contributes to further rapid growth associated necessarily with environmental exploitation.

Growth in natural systems, whatever the level of those systems, cannot continue at an uncontrolled rate indefinitely. Either internal mechanisms or the external environment must of necessity ultimately trigger diminishing growth and hopefully lead to a steady state system characterized by slower growth rates with emphasis on quality maintenance of the system. Thus, the strategy of unrestricted growth and wasteful exploitation of the environment must ultimately be replaced by the strategy of survival.

The impact of our youthful exploitive attitude to the environment is experienced to an ever-increasing degree in our daily lives. Daily we are confronted with the reality that our natural ecosystems and environment are limited in their abilities to absorb and detoxify our waste products. Daily we are confronted by a spectrum of biologically degradable and non-degradable waste contaminants, many of which have proved harmful to man and some of which have triggered chain reactions within the natural ecosystems which compose our biosphere and have previously rendered that biosphere a suitable habitat for man.

The intelligent utilization of our limited resources would require a fundamental knowledge of the impact of man on his environment. Included would be a knowledge of the synergistic effects of waste contaminants upon the natural ecosystems. Yet we as scientists can provide at this time only fragmentary evidence of the environmental impact and consequences of any one of these contaminants, and knowledge of the synergistic interactions of contaminants is almost totally lacking.

As Professor Khan has pointed out, the chlorinated hydrocarbon pesticides can be long lived in our natural ecosystems. Certainly an extensive literature now exists on the production, application and ecological consequences of these chlorinated hydrocarbon pesticides. For example, the fate of DDT in our ecosystems and its biological consequences have been examined in several recent studies. Yet in spite of this literature we continue to use this substance in enormously large quantities on this planet. This course of action is risky at best since the effects of long-term exposure to these chemicals have not yet been established in man or natural ecosystems. It is not the purpose of this introduction to present arguments for the elimination of such pesticide usage, and indeed such a discussion is beyond the scope of the present paper. Needless to say, both pest control and pesticide control are ecological problems of prime importance that require our immediate attention. It is our purpose to spotlight the fragmentary nature of our knowledge of the effects of environmental contaminants. We as scientists have been occupied elsewhere and have only recently turned our attention to these major ecological questions.

As indicated above, I believe that the transition from the transient to the steady state, from the youthful-exploitive to the mature-quality maintenance state will require considerably greater understanding of the environmental impact of waste contaminants on our natural ecosystem. It is extremely opportune, then, that Professor Khan has organized this major symposium on "Mechanisms of Survival in Toxic Environments." The contributions in this symposium should allow us to assess more fully the state of our knowledge with regard to the effects of selected environmental contaminants, and hopefully allow us to make better judgments as to the directions of our future ecological efforts.

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# PREFACE

The material presented in this volume addresses itself to chemical environmental pollutants in general, their fate and disposition in our environment, and their bio-environmental effects. Toward these goals the textual topics have been divided into five categories as shown below. The specific pollutants and/or toxicants include the following: pesticides (insecticides, herbicides, nematocides, fungicides, acaricides), crude and refined oils, polychlorinated biphenyls, polycyclic aromatic hydrocarbons (carcinogens), nitrilotriacetic acid, lead, carbon monoxide and other supposedly less ominous xenobiotics. The dispositions of these substances and the effects of certain of them were studied in either ecosystems and/or organisms, or components thereof.

I. Impact of chemical pollutants on the biology of organisms –
   DDT–The clear lake ecosystem model
   Pesticides–Population biology and evolution of species
   Halogenated Hydrocarbons–Concentrations in estuarine birds and reproduction
   Oils, Mercury, PCB's–Adaptation and survival of clams crabs, oysters and shrimps
II. Detoxication mechanisms of survival in toxic environments–
   Halogenated Hydrocarbons–Fate in microbes, houseflies, and fish.
III. Role of the mixed-function oxidase and its components in survival in toxic environments –
   Cytochrome P-450–Pesticide interactions and genetics in insects and microbes
   Aryl Hydrocarbon Hydroxylase – Effects upon mammalian cells in culture

IV. Recent trends in pesticide research –
Current Research – Physicochemical considerations, photolysis, resistance (research, ecologic and economic aspects), costs and benefits.

V. Non-Pesticidal Pollutants –
Secondary Effects – NTA (a detergent builder), lead and carbon monoxide (from molecules to microbes, man, and the environment)

In Section I various pollutants are considered in relation to the following ecosystems: Clear Lake, CA; East Coast South of New York; Tidewater Marsh; Global. The considerations span the chasm from the computer-assisted modeling by Drs. Craig and Rudd and considerations of population dynamics by Drs. Pimentel and Goodman to the tissue concentrations of toxicants that are discussed by Drs. Ohlendorf and Anderson and colleagues. This section convincingly documents the global nature of environmental pollution by synthetic chemicals and describes the evolutionary and more short-term effects of these toxicants. Section II on the other hand covers the molecular modifications of the pesticides and other xenobiotics that are produced by the environmental constituents. These two initial sections thus describe our ability to create toxic environments and the abilities of the environments and residents therein to adapt to the toxic insults. Section III extends this latter aspect via coverage of one system (P-450, mixed-function oxygenase), detailing its role in altering the toxicities of chemical environmental pollutants and the genetic control and expression of this metabolic function. The topics in Section IV afford a view of several current areas of research on environmental pollutants from the molecular to the organismic with an emphasis on resistance to the effects of insecticides. The humanistic and monetary costs and human economic and ecologic benefits of pesticides are herein covered by Dr. Decker. His perspective in the form of an overview certainly presents a sound case for our continued dependence upon synthetic chemicals, and, thus, our need for the most advanced information and planning in this area of human endeavor. In the terminal section (V), the life-cycles of environmental chemicals are detailed as per their origins and fates in some environmental life-cycles and ecosystems. The terminal paper in the volume deals with lead in plant and animal environments including the human, and changes in a cardiovascular system as a result of exposure to a toxic environment composed of graded amounts of carbon monoxide.

The scope of the information thus presented is very broad as is our concept of environmental toxicology. However, we feel that the individual topics that are presented toward this broad coverage are very detailed and, in fact, represent the current research and conceptual conditions in the

areas. Thus, the volume is appropriate to the needs of the novice in this area of toxicology where a general appreciation is desired and will satisfy the needs of teachers and research workers and administrators involved in considerations of toxicants in OUR environment.

The purposes for preparing this volume were few and seemingly not complicated:

To present in a comprehensive and useful manner reports on chemically contaminated ecosystems and organisms thus affording documentation of the existence of toxic environments

To describe in the available and necessary detail the origins, extent, and some consequences of chemical environmental pollution

To detail the evolutionary aspects of existence in toxic environments with emphasis on and specific reference to pesticide effects both toxic or lethal and resistance to pesticides in insects and many organisms other than the human.

To indicate some previous and current directions in pesticide and non-pesticidal research and their economic, ecologic, and humanistic costs and benefits.

To these ends, the editors and authors trust that they have been at least partially successful. If the material presented herein contributes to our arriving at an environment that affords minimal toxicity to humankind, then our efforts will have been even more rewarding.

Waxing strictly editorially, we have taken considerable lattitude and allowed same in terms of the overall composition of the book. For example, the letter u and the character $\mu$ are used in different places to indicate the same concept relating to amounts of materials (micro), the legends and titles to the figures and tables are not strictly placed in the same relative position even within a single report due to considerations of emphasis and space, literature citations are of a generally accepted format except that those references that we considered more obscure were presented in greater detail. Other and similar examples of commission and any omissions are strictly attributable to the editors. Special acclaim must be given to Pat Feeley McDonald and Mary Anderson for their compositional skills in the actual preparation of the textual materials for the camera-ready format.

M. A. Q. Khan
J. P. Bederka

# INTRODUCTION

*M. A. Q. KHAN*

The greatest contribution of scientific knowledge to human health and comfort has come from the use of chemicals. The production and usage of synthetic organic chemicals has enormously increased during the last thirty-four years (10 billion pounds produced in 1943 and 138 billion pounds in 1970) (Pitts and Metcalf, 1969; Stoker and Seager, 1972). The use of synthetic organic chemicals in agriculture, medicine, nutrition, hygiene, etc., has resulted in an increased mean human longevity and thus caused population explosions in most countries. This has put demands on increased food and fiber production and has made man become more dependent on the use of synthetic chemicals.

Unfortunately, the knowledge that enabled man to use the resources of the biosphere to his advantage, somehow, allowed us to overlook the effects that these synthetic chemicals could cause on the biota. These chemicals, after their application, are not confined to the target organism because they are not taken up and degraded completely by the target organism. The non-target organisms can become directly contaminated if the chemical is applied to an open field, forest, a body of water or indirectly by eating contaminated food (pesticides, industrial effluents, fertilizers, etc.). If the particular chemical is refractive to physicochemical and biochemical degradation it can persist in various living and nonliving components of the environment for several years, e.g., DDT, dieldrin, polychlorinated biphenyls, lead and mercury. Biological effects of these chemical contaminants become intensified if they are toxic against living organisms at low concentrations. This is true of certain broad-spectrum residual pesticides.

The U. S. A. alone produces about one billion pounds of approximately 1,000 pesticidal chemicals which are used in 60,000 different formulations (Kearney, 1973). All of the environmental pollution with these toxicants has occurred after 1941 when their industrial synthesis began. The contamination of soils, water, and living organisms, with pesticides such as DDT and dieldrin has greatly concerned scientists, regulatory agencies and the general public.

Besides pesticides, the U. S. A. alone produced 137 billion pounds of synthetic organic chemicals in 1970, and their number is increasing by at least 10 per cent each year. Of these, fertilizers account for 29 billion pounds and detergents 5 billion pounds (Stoker and Seager, 1972). At least 75 billion gallons of gasoline are used every year in this country, thus, releasing, through the automobile exhaust 300 million pounds of lead, 100 million tons of carbon monoxide, 4 million tons of oxides of nitrogen, and several million tons of other pollutants into the environment (Anonymous, 1968). HOW THESE CHEMICALS AFFECT LIVING ORGANISMS AND HOW THEY ARE DEGRADED ARE THE SUBJECTS OF THIS VOLUME. The fate of the environmental contaminants in living organisms is examined at the population, organismal and molecular level. Emphasis has been placed on the pathways and mechanisms of detoxication of the toxic chemical pollutants which enable organisms to dispose of these toxic xenobiotics. The scientists who are participating in this symposium have reviewed the current status of knowledge in various biochemical and ecological aspects of environmental contamination. Since no single book or conference can encompass the problems of environmental pollution, more conferences and more knowledge is needed before conclusions can be made about the ability of living organisms to succumb to or to accomodate the chemical contaminants in their environments.

I am grateful to the Division of Comparative Physiology and Biochemistry of the American Society of Zoologists for assistance in organizing this symposium. Special thanks are due to Drs. Ann E. Kammer, Michael J. Greenberg and L. B. Kirshner for their encouragement and constant support.

The success of this symposium is due to the participating scientists whose courage and wisdom inspired me throughout the symposium. I am confident that the knowledge which took us to outer space will not fail us in our understanding and solving the problems created by the usage of synthetic chemicals. I am especially grateful to Drs. R. L. Rudd, R. W. Estabrook, E. Hodgson, R. H. Adamson and D. Pimentel who in spite of difficulties in traveling here are at this symposium. Their constant advice and guidance has been greatly appreciated. I am highly honored by the help that Dr. Elmer B. Hadley offered me and by his presence here to inaugurate the symposium.

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