Reviews of Environmental Contamination & Toxicology

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Continuation of Residue Reviews

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Foreword

International concern in scientific, industrial, and governmental communities over traces of xenobiotics in foods and in both abiotic and biotic environments has justified the present triumvirate of specialized publications in this field: comprehensive reviews, rapidly published research papers and progress reports, and archival documentations. These three international publications are integrated and scheduled to provide the coherency essential for nonduplicative and current progress in a field as dynamic and complex as environmental contamination and toxicology. This series is reserved exclusively for the diversified literature on "toxic" chemicals in our food, our feeds, our homes, recreational and working surroundings, our domestic animals, our wildlife and ourselves. Tremendous efforts worldwide have been mobilized to evaluate the nature, presence, magnitude, fate, and toxicology of the chemicals loosed upon the earth. Among the sequelae of this broad new emphasis is an undeniable need for an articulated set of authoritative publications, where one can find the latest important world literature produced by these emerging areas of science together with documentation of pertinent ancillary legislation.

Research directors and legislative or administrative advisers do not have the time to scan the escalating number of technical publications that may contain articles important to current responsibility. Rather, these individuals need the background provided by detailed reviews and the assurance that the latest information is made available to them, all with minimal literature searching. Similarly, the scientist assigned or attracted to a new problem is required to glean all literature pertinent to the task, to publish new developments or important new experimental details quickly, to inform others of findings that might alter their own efforts, and eventually to publish all his/her supporting data and conclusions for archival purposes.

In the fields of environmental contamination and toxicology, the sum of these concerns and responsibilities is decisively addressed by the uniform, encompassing, and timely publication format of the Springer-Verlag (Heidelberg and New York) triumvirate:

Reviews of Environmental Contamination and Toxicology [Vol. 1 through 97 (1962–1986) as Residue Reviews] for detailed review articles concerned with any aspects of chemical contaminants, including pesticides, in the total environment with toxicological considerations and consequences.

Bulletin of Environmental Contamination and Toxicology (Vol. 1 in 1966) for rapid publication of short reports of significant advances and discoveries in the fields of air, soil, water, and food contamination and pollution as well as methodology and other disciplines concerned with the introduction, presence, and effects of toxicants in the total environment.

Archives of Environmental Contamination and Toxicology (Vol. 1 in 1973) for important complete articles emphasizing and describing original experimental or theoretical research work pertaining to the scientific aspects of chemical contaminants in the environment.

Manuscripts for *Reviews* and the *Archives* are in identical formats and are peer reviewed by scientists in the field for adequacy and value; manuscripts for the *Bulletin* are also reviewed, but are published by photo-offset from camera-ready copy to provide the latest results with minimum delay. The individual editors of these three publications comprise the joint Coordinating Board of Editors with referral within the Board of manuscripts submitted to one publication but deemed by major emphasis or length more suitable for one of the others.

Coordinating Board of Editors

Preface

Thanks to our news media, today's lay person may be familiar with such environmental topics as ozone depletion, global warming, greenhouse effect, nuclear and toxic waste disposal, massive marine oil spills, acid rain resulting from atmospheric SO_2 and NO_x, contamination of the marine commons, deforestation, radioactive leaks from nuclear power generators, free chlorine and CFC (chlorofluorocarbon) effects on the ozone layer, mad cow disease, pesticide residues in foods, green chemistry or green technology, volatile organic compounds (VOCs), hormone- or endocrine-disrupting chemicals, declining sperm counts, and immune system suppression by pesticides, just to cite a few. Some of the more current, and perhaps less familiar, additions include *xenobiotic transport, solute transport, Tiers 1 and 2, USEPA to cabinet status, and zero-discharge.* These are only the most prevalent topics of national interest. In more localized settings, residents are faced with leaking underground fuel tanks, movement of nitrates and industrial solvents into groundwater, air pollution and "stay-indoors" alerts in our major cities, radon seepage into homes, poor indoor air quality, chemical spills from overturned railroad tank cars, suspected health effects from living near high-voltage transmission lines, and food contamination by "flesh-eating" bacteria and other fungal or bacterial toxins.

It should then come as no surprise that the '90s generation is the first of mankind to have become afflicted with *chemophobia*, the pervasive and acute fear of chemicals.

There is abundant evidence, however, that virtually all organic chemicals are degraded or dissipated in our not-so-fragile environment, despite efforts by environmental ethicists and the media to persuade us otherwise. However, for most scientists involved in environmental contaminant reduction, there is indeed room for improvement in all spheres.

Environmentalism is the newest global political force, resulting in the emergence of multi-national consortia to control pollution and the evolution of the environmental ethic. Will the new politics of the 21st century be a consortium of technologists and environmentalists or a progressive confrontation? These matters are of genuine concern to governmental agencies and legislative bodies around the world, for many serious chemical incidents have resulted from accidents and improper use.

For those who make the decisions about how our planet is managed, there is an ongoing need for continual surveillance and intelligent controls to avoid endangering the environment, the public health, and wildlife. Ensuring safety-in-use of the many chemicals involved in our highly industrial-

ized culture is a dynamic challenge, for the old, established materials are continually being displaced by newly developed molecules more acceptable to federal and state regulatory agencies, public health officials, and environmentalists.

Adequate safety-in-use evaluations of all chemicals persistent in our air, foodstuffs, and drinking water are not simple matters, and they incorporate the judgments of many individuals highly trained in a variety of complex biological, chemical, food technological, medical, pharmacological, and toxicological disciplines.

Reviews of Environmental Contamination and Toxicology continues to serve as an integrating factor both in focusing attention on those matters requiring further study and in collating for variously trained readers current knowledge in specific important areas involved with chemical contaminants in the total environment. Previous volumes of *Reviews* illustrate these objectives.

Because manuscripts are published in the order in which they are received in final form, it may seem that some important aspects of analytical chemistry, bioaccumulation, biochemistry, human and animal medicine, legislation, pharmacology, physiology, regulation, and toxicology have been neglected at times. However, these apparent omissions are recognized, and pertinent manuscripts are in preparation. The field is so very large and the interests in it are so varied that the Editor and the Editorial Board earnestly solicit authors and suggestions of underrepresented topics to make this international book series yet more useful and worthwhile.

Reviews of Environmental Contamination and Toxicology attempts to provide concise, critical reviews of timely advances, philosophy, and significant areas of accomplished or needed endeavor in the total field of xenobiotics in any segment of the environment, as well as toxicological implications. These reviews can be either general or specific, but properly they may lie in the domains of analytical chemistry and its methodology, biochemistry, human and animal medicine, legislation, pharmacology, physiology, regulation, and toxicology. Certain affairs in food technology concerned specifically with pesticide and other food-additive problems are also appropriate subjects.

Justification for the preparation of any review for this book series is that it deals with some aspect of the many real problems arising from the presence of any foreign chemical in our surroundings. Thus, manuscripts may encompass case studies from any country. Added plant or animal pest-control chemicals or their metabolites that may persist into food and animal feeds are within this scope. Food additives (substances deliberately added to foods for flavor, odor, appearance, and preservation, as well as those inadvertently added during manufacture, packing, distribution, and storage) are also considered suitable review material. Additionally, chemical contamination in any manner of air, water, soil, or plant or animal life is within these objectives and their purview.

Normally, manuscripts are contributed by invitation, but suggested topics are welcome. Preliminary communication with the Editor is recommended before volunteered review manuscripts are submitted.

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Persistent Pesticides in Mexico

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I. Introduction

In June 1995, an International Experts Meeting on Persistent Organic Pollutants, convened to explore the global dimensions of the persistent organic pollutant problem and to promote opportunities for global action, took place in Canada. Among the objectives of the meeting were to highlight the concerns posed to human health and the environment by certain persistent organic pollutants (POPs) and to identify the technical, institutional, social, economical, financial, and management issues inherent to these chemicals. During the meeting, it became evident that, in contrast to the situation in developed countries, in most developing countries (including Mexico) there is an important lack of information on the uses and environmental presence of these pollutants and that it is precisely in most of these coun-

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tries that the use of POPs has not been controlled, despite the growing scientific evidence of the health and environmental hazards associated with them.

One of the more important groups of POPs are the persistent organochlorine pesticides. In Mexico, the presence of these pesticides in the environment, food, and human tissues has not been considered an important problem or sufficiently studied. Furthermore, until very recently, the production, import, and use of several of these pesticides were not restricted at all, and even where some restrictions existed, they were established mainly as a result of international pressure, have not been fully implemented, and are not adequately enforced.

Although there are many reasons for this shortcoming, probably one of the major factors has been the lack of information and awareness at the higher political and decision levels about the scientifically documented local, regional, and global long-term environmental and health problems that could result from the widespread production, use, and disposal of these chemicals. As a consequence, the priority assigned to develop an adequate legal framework for the effective control of these pollutants and to establish the required technical and scientific infrastructure has been, in the best of cases, very low. This lack of information and awareness has also contributed to the widespread import and use of persistent pesticides in Mexico after they were withdrawn from other markets and, in some cases, even to the transfer to Mexico of the technology to produce and use these and other hazardous chemicals.

In this context, the financial resources assigned to study the presence of persistent pesticide residues in the different media in Mexico have always been extremely inadequate. As a result, there are relatively few data on the presence of their residues in the environment, food, and human tissues in Mexico, and with those available at present it is not possible to establish valid environmental patterns, evaluate the present situation, or to provide scientific justifications to update the restrictions, tighten the law, improve enforcement, and increase the resources for control, research, and surveillance.

This review is the first effort to put together the available information on the use of persistent pesticides in Mexico, to assess the legal framework for their control, and to collect and analyze the existing data on their residues in the environment, biota, food, and the tissues of people in Mexico.

II. Background

As is the case for most countries, chemical pollution by pesticides was not important in Mexico prior to 1945: agricultural practices were traditional, with very low or no use of chemicals, except on cotton; in any case, only natural or inorganic pesticides were used (Flores-Cáceres 1984). However,

after the second world war, organochlorine pesticides, particularly DDT (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl) ethane) were introduced and intensively used thereafter in the country both for agricultural purposes and as part of the internationally supported câmpaign to eradicate malaria (Bordas 1973; Martínez-Saldaña 1986; Wright 1990).

DDT and other organochlorine pesticides, such as toxaphene and BHC, were used in large quantities in Mexico during the 1950s and the early 1960s (Narro 1979). Because these were mostly imported, the Mexican government considered this economically inadequate and, through the state-owned company Guanos y Fertilizantes Mexicanos (GUANOMEX), later Fertilizantes Mexicanos, or FERTIMEX, acquired the DDT- and BHC-producing company Montrose Mexicana and the chlorinated terpene and camphene producer Lerma Industrial in 1968 (Grasso 1971). In the early 1970s GUANOMEX obtained also the technology to produce ethyl parathion, methyl parathion, and malathion (Narro 1979). As has been the case with other hazardous chemicals, the national production of these pesticides and the Mexican government's involvement in it started just after concern about their environmental hazards was being raised in other countries and well before an adequate legal framework for their control existed in Mexico (see Section III).

The local production of organochlorine (OC) pesticides increased their availability and guaranteed a low price; as a result, their use was encouraged, leading to the widespread presence of their residues in all types of food and in the environment. In the early 1970s, the growing concern of the USFDA authorities about the frequent violatory levels of highly persistent residues (usually DDT and its derivatives) in most food commodities imported from Mexico was the driving force for the first official Mexican effort to install several residue labs in the major agricultural areas of the country, in theory to continuously verify the residue levels in export commodities and certify their compliance with United States tolerances; however, this and later similar efforts have not been particularly successful. This concern and the related pressure also promoted the accelerated change from OC pesticides to organophosphates and carbamates in the areas devoted to export agriculture and eventually caused the split of Mexican agriculture into two major sectors. One sector is devoted to export crops, where there is some control as to which pesticides are used and how are they used, and another sector is devoted to crops for the local markets or self-consumption, where OC pesticides produced by FERTIMEX or by subsidiaries of foreign companies continued to be in general use until the early 1990s and where controls are still mostly theoretical (Goodman 1987; Restrepo 1992).

This pressure to protect the health of the consumers in other countries has had extremely undesirable consequences for the health of Mexicans, in particular the applicators of the pesticides. To ensure that any residues were degraded by the time the commodities reached the final consumer, persis-

tent pesticides of relatively low acute toxicity were substituted by products of low persistence but high acute toxicity, such as parathion, azinphos-methyl, metamidophos, or carbofuran. Due to insufficient information and training, the new products were and are still handled with the same lack of protection as the former, greatly increasing the hazards for agricultural workers in the regions devoted to export agriculture and creating a public health problem that has not been addressed at all (Wright 1986, 1988, 1990).

Because a use for the large quantities of persistent pesticides produced by FERTIMEX had to be found, these products were widely distributed by several government agencies, in particular the state-owned bank for the support of agriculture, Banco Nacional de Crédito Rural (BANRURAL), and the state agency Servicios Ejidales, either heavily subsidized or through tied loans, especially to small farmers or to "ejidatarios." Therefore, their residues continued to build up in the environment, food, and humans in Mexico.

It was not until 1988, with the creation of the Comisión Intersecretarial para el Control del Proceso y Uso de Plaguicidas, Fertilizantes y Sustancias Tóxicas (Interministerial Commission for the Control of the Process and Use of Pesticides, Fertilizers, and Toxic Chemicals), known as CICOPLAFEST (Diario Oficial de la Federación 1987, 1988), that a series of changes started that have resulted in the relatively recent restriction or banning of most of the persistent pesticides previously produced and used in Mexico. However, there is still a long road ahead; for example, several persistent pesticides are still included in the most recent official list of pesticides registered for use in Mexico (CICOPLAFEST 1994), and DDT can still be produced, under a specific request by the health authorities, to be used in public health campaigns.

III. Legal Framework

In Mexico, to be complete and enforceable, legislation requires a constitutional basis, the explicit mention of the problem in a particular law, the existence of all of the specific regulations mentioned in the law, and the development of the full set of official standards (Normas Oficiales Mexicanas or NOMs) that should specify the technical details for the control; for example, in the case of pesticide residues in food, the sampling and analysis methodology or the tolerances (Brañes 1994; González-Márquez 1994).

In addition to these legal requirements, it is evident that an adequate administrative and technical infrastructure with sufficient highly qualified personnel to implement the law and to carry on the oversight and enforcement procedures, including any required analyses, should also exist. There should be, as well, a strong and respected scientific community, aware of any potential short- and long-term problems, with enough financial sup-

port, capable of providing sufficient valid data, and willing to advise the authorities about the importance of the control and the significance of any findings and to participate actively in the decision-making process.

Unfortunately, the legal framework and associated technical and administrative infrastructure for the control of hazardous and toxic substances in Mexico is generally inadequate. Although to date the legislation for the control of pesticides is the most complete of those regulating hazardous and toxic substances in the country (Albert and Aranda 1986), it still has many deficiencies that hamper or prevent its enforcement. In the first place, its development has been extremely slow and haphazard; as a result, synthetic pesticides had been in use in Mexico for many years, or the technology to produce them already installed, before a scientifically based and complete registration process for pesticides was established in the country.

For example, until 1974 the act on which all regulations on pesticides should have been based was the extremely outdated and incomplete "Ley de Sanidad Fitopecuaria de los Estados Unidos Mexicanos" (SAG 1940), approved well before any synthetic pesticides were commercialized in Mexico. Further, of the additional regulations and norms that should have complemented this law to make it enforceable, during the period 1940–1974 only the 1942 "Reglamento de la Ley" was issued. Furthermore, instead of issuing legally binding regulations and norms, for many years the Ministry of Agriculture used to publish "circulars," such as Circular No. 6 on the restrictions for endrin (SAG 1967), and "agreements," such as the "Acuerdo" on the sanitary norms to regulate the import, manufacture, transport, trade, and use of pesticides (SAG 1968), although the authorities should have been aware that these documents could not be properly enforced. As a further example of the very slow development of the legal framework for pesticides, it should be mentioned that, during 1970, the Secretaría de Agricultura y Ganadería (SAG) established a committee to develop a bill to regulate most pesticide-related issues (Grasso 1971); although there were some achievements, this bill had not been completed by the time CICOPLAFEST was created.

The same deficiencies in the development of the legal framework were evident years later in the very slow development of the regulations and standards essential to complement the laws on health (SSA 1984) and on the environment (SEDUE 1988) so as to implement any restrictions on pesticides mentioned in these laws and make them enforceable. Finally, from the time of the introduction of synthetic pesticides in Mexico until 1988, the only authority with a mandate for their control was the Ministry of Agriculture (Secretaría de Agricultura); therefore, during 40 years the potential adverse human health and environmental effects (and indirect related costs) were not taken into account in the decisions about the production, import, use, and disposal of these chemicals in Mexico.

In recent years, partially as a result of the growing global concern about persistent pollutants and of the international agreements of Mexico, such

as the North American Free Trade Agreement (NAFTA), this situation has been slowly changing; however, although there have been some positive changes in the legislation for the control of pesticides, the legal framework that should be the basis for the sound management of these and other hazardous and toxic chemicals, including the establishment of scientifically based restrictions, the proper enforcement of regulations, and the development of an integral system for the control of their production, import, transportation, storage, handling, use, and disposal, is in the best of cases still in the early stages.

In summary, many of the regulations and standards essential for the control of hazardous and toxic chemicals, including persistent pesticides, are still lacking in the Mexican legislation and, due to the severe deficiencies in the related administrative or technical infrastructure, which are still far behind the present legal framework and the needs of the country, the law cannot be fully implemented, nor can the relatively few existing regulations and standards be properly enforced. The low priority assigned by the science and technology authorities (CONACYT) for research on the health and environmental effects of these chemicals contributes to this situation because the scientific community lacks adequate resources, support, and motivation for this type of research.

IV. Production and Uses

Mexico has been, with Brazil, one of the major Latin American producers of OC pesticides; in addition to their uses in public health campaigns, for a long time OCs were very important for the agriculture of the country. It has been calculated that, during the 1950s and the early 1960s, 12 tonnes/year of OCs were used in Mexico (Narro 1979). Before 1970, Mexico had approximately 60% of the installed capacity to produce DDT in Latin America, and it has been reported that as much as 1% of the world production of DDT was used in the cotton-growing region known as Comarca Lagunera (Bordas 1973).

FERTIMEX (1981) reported that during 1969–1979 the use of all OC pesticides in Mexico averaged approximately 9000 tonnes/year, with domestic yearly production levels estimated to be 3900 tonnes of DDT, 2000 tonnes of toxaphene, approximately 1600 tonnes of BHC, and 300 tonnes of endrin. The total domestic production of OC insecticides for those years was 42,600 tonnes of DDT, 20,800 tonnes of toxaphene, 17,500 tonnes of BHC, and 2500 tonnes of endrin. In addition to these products, 22 other OC insecticides were imported during the same period. The yearly DDT production by FERTIMEX (installed capacity, 4000 tonnes/year) and Diamond Shamrock (installed capacity, 1000 tonnes/year) was equivalent to 80% of capacity during this period. The import of OC pesticides peaked in 1958, at almost 12,000 tonnes, and declined drastically thereafter, as the domestic production of some of these chemicals increased. Virtually no DDT was imported after 1970, when Mexico became self-sufficient in this