IPCS International Programme on Chemical Safety

Environmental Health Criteria 83

DDT and its Derivatives — Environmental Aspects

Published under the joint sponsorship of the United Nations Environment Programme, the International Labour Organisation, and the World Health Organization

WORLD HEALTH ORGANIZATION GENEVA 1989

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CONTENTS

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CONTENTS

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NOTE TO READERS OF THE CRITERIA DOCUMENTS

Every effort has been made to present information in the criteria documents as accurately as possible without unduly delaying their publication. In the interest of all users of the environmental health criteria documents, readers are kindly requested to communicate any errors that may have occurred to the Manager of the International Programme on Chemical Safety, World Health Organization, Geneva, Switzerland, in order that they may be included in corrigenda, which will appear in subsequent volumes.

* * *

A detailed data profile and a legal file can be obtained from the International Register of Potentially Toxic Chemicals, Palais des Nations, 1211 Geneva 10, Switzerland (Telephone no. 988400 - 985850).

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ENVIRONMENTAL HEALTH CRITERIA FOR DDT AND ITS DERIVATIVES - ENVIRONMENTAL ASPECTS

A WHO Task Group on Environmental Health Criteria for DDT and its Derivatives - Environmental Aspects met at the Institute of Terrestrial Ecology, Monks Wood, United Kingdom, from 14 to 18 December 1987. Dr I. Newton welcomed the participants on behalf of the host institution, and Dr M. Gilbert opened the meeting on behalf of the three co-sponsoring organizations of the IPCS (ILO/UNEP/WHO). The Task Group reviewed and revised the draft criteria document and made an evaluation of the risks for the environment from exposure to DDT and its derivatives.

The first draft of this document was prepared by Dr S. Dobson and Mr P.D. Howe, Institute of Terrestrial Ecology. Dr M. Gilbert and Dr P.G. Jenkins, both members of the IPCS Central Unit, were responsible for the overall scientific content and editing, respectively.

* * *

Partial financial support for the publication of this criteria document was kindly provided by the United States Department of Health and Human Services, through a contract from the National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina, USA - a WHO Collaborating Centre for Environmental Health Effects.

INTRODUCTION

There is a fundamental difference in approach between the toxicologist and the ecotoxicologist concerning the appraisal of the potential threat posed by chemicals. The toxicologist, because his concern is with human health and welfare, is preoccupied with any adverse effects on individuals, whether or not they have ultimate effects on performance or survival. The ecotoxicologist, in contrast, is concerned primarily with the maintenance of population levels of organisms in the environment. In toxicity tests, he is interested in effects on the performance of individuals - in their reproduction and survival - only insofar as these might ultimately affect the population size. To him, minor biochemical and physiological effects of toxicants are irrelevant if they do not, in turn, affect reproduction, growth, or survival.

It is the aim of this document to take the ecotoxicologist's point of view and consider effects on populations of organisms in the environment. The risk to human health of the use of DDT was evaluated in Environmental Health Criteria 9: DDT and its Derivatives (WHO, 1979). This document did not consider effects on organisms in the environment, but did consider environmental levels of DDT likely to arise from recommended uses. No attempt has been made here to reassess the human health risk; the interested reader should refer to the original document, which contains the relevant literature in this area.

This document, although based on a thorough survey of the literature, is not intended to be exhaustive in the material included. In order to keep the document concise, only those data which were considered to be essential in the evaluation of the risk posed by DDT to the environment have been included.

The term bioaccumulation indicates that organisms take up chemicals to a greater concentration than that found in their environment or their food. 'Bioconcentration factor' is a quantitative way of expressing bioaccumulation: the ratio of the concentration of the chemical in the organism to the concentration of the chemical in the environment or food. Biomagnification refers, in this document, to the progressive accumulation of chemicals along a food chain.

1. SUMMARY AND CONCLUSIONS

1.1 Physical and Chemical Properties

DDT is an organochlorine insecticide which is a white crystalline solid, tasteless and almost odourless. Technical DDT, which is principally the *p,p'* isomer, has been formulated in almost every conceivable form.

1.2 Uptake, Accumulation, and Degradation

The physicochemical properties of DDT and its metabolites enable these compounds to be taken up readily by organisms. High lipid solubility and low water solubility lead to the retention of DDT and its stable metabolites in fatty tissue. The rates of accumulation into organisms vary with the species, with the duration and concentration of exposure, and with environmental conditions. The high retention of DDT metabolites means that toxic effects can occur in organisms remote in time and geographical area from the point of exposure.

These compounds are resistant to breakdown and are readily adsorbed to sediments and soils that can act both as sinks and as long-term sources of exposure (e.g., for soil organisms).

Organisms can accumulate these chemicals from the surrounding medium and from food. In aquatic organisms, uptake from the water is generally more important, whereas, in terrestrial fauna, food provides the major source.

In general, organisms at higher trophic levels tend to contain more DDT-type compounds than those at lower trophic levels.

Such compounds can be transported around the world in the bodies of migrant animals and in ocean and air currents.

1.3 Toxicity to Microorganisms

Aquatic microorganisms are more sensitive than terrestrial ones to DDT.

An environmental exposure concentration of 0.1 μg/litre can cause inhibition of growth and photosynthesis in green algae.

Repeated applications of DDT can lead to the development of tolerance in some microorganisms.

There is no information concerning the effects on species composition of microorganism communities. Therefore, it is difficult to extrapolate the relevance of single-culture studies to aquatic or terrestrial ecosystems. However, since microorganisms are basic in food chains, adverse effects on their populations would influence ecosystems. Thus, DDT and its metabolites should be regarded as a major environmental hazard.

1.4 Toxicity to Aquatic Invertebrates

Both the acute and long-term toxicities of DDT vary between species of aquatic invertebrates. Early developmental stages are more sensitive than adults to DDT. Long-term effects occur after exposure to concentrations ten to a hundred times lower than those causing short-term effects.

DDT is highly toxic, in acute exposure, to aquatic invertebrates at concentrations as low as 0.3 μg/litre. Toxic effects include impairment of reproduction and development, cardiovascular modifications, and neurological changes. Daphnia reproduction is adversely affected by DDT at 0.5 μg/litre.

The influence of environmental variables (such as temperature, water hardness, etc.) is documented but the mechanism is not fully understood. In contrast to the data on DDT, there is little information on the metabolites DDE or TDE. The reversibility of some effects, once exposure ceases, and the development of resistance have been reported.

1.5 Toxicity to Fish

DDT is highly toxic to fish; the 96-h LC_{50}s reported (static tests) range from 1.5 to 56 μg/litre (for largemouth bass and guppy, respectively). Smaller fish are more susceptible than larger ones of the same species. An increase in temperature decreases the toxicity of DDT to fish.

The behaviour of fish is influenced by DDT. Goldfish exposed to 1 μg/litre exhibit hyperactivity. Changes in the feeding of young fish are caused by DDT levels commonly found in nature, and effects on temperature preference have been reported.

Residue levels of > 2.4 mg/kg in eggs of the winter flounder result in abnormal embryos in the laboratory, and comparable residue levels have been found to relate to the death of lake trout fry in the wild.

Cellular respiration may be the main toxic target of DDT since there are reports of effects on ATPase.

The toxicity of TDE and DDE has been less studied than that of DDT. However, the data available on rainbow trout and bluegill sunfish show that TDE and DDE are both less toxic than DDT.

1.6 Toxicity to Amphibians

The toxicity of DDT and its metabolites to amphibians varies from species to species; although only a few data are available, amphibian larvae seem to be more sensitive than adults to DDT. TDE seems to be more toxic than DDT to amphibians, but there are no data available for DDE. All the studies reported have been static tests and, therefore, results should be treated with caution.

1.7 Toxicity to Terrestrial Invertebrates

There have been few reports on the effects of DDT and its metabolites on non-target terrestrial invertebrates.

Earthworms are insensitive to the acutely toxic effects of these compounds at levels higher than those likely to be found in the environment. The uptake of DDT by earthworms is related to the concentrations in soil and to the activity of the worms; seasonally greater activity increases uptake. Thus, although earthworms are unlikely to be seriously affected by DDT, they pose a major hazard to predators because of the residues they can tolerate.

Both DDT and DDE are classified as being relatively non-toxic to honey bees, with a topical LD_{50} of 27 μg/bee.

There are no reports on laboratory studies using DDE or TDE, in spite of the fact that these are major contaminants of soil.

1.8 Toxicity to Birds

DDT and its metabolites can lower the reproductive rate of birds by causing eggshell thinning (which leads to egg breakage) and by causing embryo deaths. However, different groups of birds vary greatly in their sensitivity to these chemicals; predatory birds are extremely sensitive and, in the wild, often show marked shell thinning, whilst gallinaceous birds are relatively insensitive. Because of the difficulties of breeding birds of prey in captivity, most of the experimental work has been done with insensitive species, which have often shown little or no shell thinning. The few studies on more sensitive species have shown shell thinning at levels similar to those found in the wild. The lowest dietary concentration of DDT reported to cause shell thinning experimentally was 0.6 mg/kg for the black duck. The mechanism of shell thinning is not fully understood.

1.9 Toxicity to non-laboratory Mammals

Experimental work suggests that some species, notably bats, may have been affected by DDT and its metabolites. Species which show marked seasonal cycles in fat content are most vulnerable, but few experimental studies on such species have been made. In contrast to the situation in birds, where the main effect of DDT is on reproduction, the main known effect in mammals is to increase the mortality of migrating adults. The lowest acute dose which kills American big brown bats is 20 mg/kg. Bats collected from the wild (and containing residues of DDE in fat) die after experimental starvation, which simulates loss of fat during migration.

2. PHYSICAL AND CHEMICAL PROPERTIES OF DDT AND RELATED COMPOUNDS

The term DDT is generally understood throughout the world and refers to *p,p'*-DDT (1,1'-[2,2,2-trichloroethylidine]-bis [4-chlorobenzene]). The compound's structure permits several different isomeric forms, such as *o,p'*-DDT (1-chloro-2-[2,2,2-trichloro-1-(4-chlorophenyl) ethyl] benzene). The term DDT is also applied to commercial products consisting predominantly of *p,p'*-DDT with smaller amounts of other compounds. A typical example of technical DDT had the following constituents: *p,p'*-DDT, 77.1%; *o,p'*-DDT, 14.9%; *p,p'*-TDE, 0.3%; *o,p'*-TDE, 0.1%; *p,p'*-DDE, 4%; *o,p'*-DDE, 0.1%; and unidentified products, 3.5%.

All isomers of the compound DDT are white, crystalline, tasteless, almost odourless solids, with the empirical formula $C_{14}H_9Cl_5$ and a relative molecular mass of 354.5. The melting range of *p,p'*-DDT is 108.5 to 109 °C and its vapour pressure is 2.53×10^{-5} Pa (1.9×10^{-7} mmHg) at 20 °C. DDT is soluble in organic solvents as follows (g/100 ml): benzene, 106; cyclohexanone, 100; chloroform, 96; petroleum solvents, 4-10; ethanol, 1.5. It is highly insoluble in water (solubility approximately 1 μg/litre) but very soluble in animal fats. The octanol-water partition coefficient ($\log k_{ow}$) is 7.48

The chemical structure of some of the analogues of DDT is shown in Table 1. The structure of the *o,p'*- and *m,p'*-compounds can be inferred from those of the *p,p'*-isomers presented in the table. The table is confined to compounds that occur in commercial DDT, metabolites formed from them, and analogues that have had some use as insecticides. It must be emphasized that even the commercially-available insecticidal analogues have strikingly different properties. Especially remarkable is the slow metabolism and marked storage of DDT and its metabolite DDE and the rapid metabolism and negligible storage of methoxychlor.

Technical DDT has been formulated in almost every conceivable form including solutions in xylene or petroleum distillates, emulsifiable concentrates, water-wettable powders, granules, aerosols, smoke candles, charges for vaporizers and lotions. Aerosols and other household formulations are often combined with synergized pyrethroids.

This is a summary of part of the relevant section from Environmental Health Criteria 9: DDT and its Derivatives (WHO, 1979). Further details, including information on analysis, sources of pollution, and environmental distribution can be found in this document.

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