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MARINE POLLUTION BY PESTICIDES AND POLYCHLORINATED BIPHENYLS*

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ABSTRACT

The speed with which pesticides break down into harmless constituents varies greatly between products, and is affected by factors such as climate and soil type. Some pesticides, notably the organochlorine insecticides, are broken down relatively slowly and hence have time to spread to areas far distant from their places of application. Despite their low solubility in water, these insecticides and their metabolites become widely dispersed in freshwater and marine environments. Since organisms of economic significance are very susceptible to small amounts of these insecticides, and since the insecticides can accumulate in food chains, great care should be taken to prevent unnecessary contamination of water by them.

Studies on organochlorine insecticides in the environment led indirectly to the discovery that certain industrial substances used in plastics, lubricants etc., the polychlorinated biphenyls, can also become widely distributed in freshwater and marine ecosystems. Recent studies on the ecological significance of this form of pollution are discussed.

INTRODUCTION

THE world's seas and oceans are so immense that the idea of their being seriously polluted by man-made substances may seem absurd to industrialists and agriculturalists. Therefore, it is not surprising that towns and industries discharge sewage and industrial waste into the sea throughout the world, and that a wide range of toxic materials are dumped from ships. When thought is given to the matter it is assumed that the harmful substances will become so diluted that they will cease to have any biological effects in the sea. For many substances this conclusion is known to be true or is very likely to be true. However, during the last fifty years one form of pollution, pollution by oil, has changed from being a local problem to a global one, and so it is now generally recognised that the surface waters (in which most organisms live) are vulnerable to human action. Recent work on certain insecticides and on polychlorinated biphenyls suggests that these compounds too could have biological effects on the oceans, and so they should be taken into account when the resources of the seas are considered. This paper reviews some aspects of pesticide and polychlorinated biphenyl contamination which affect or could affect the marine environment.

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The Chemicals

The compounds considered are the following :—

(*a*) Highly persistent organochlorine insecticides and their persistent metabolites :

(1) DDT (mostly pp'DDT)—an insecticide.

(2) DDE—a metabolite of DDT.

(3) TDE (DDD)—a metabolite of DDT and an insecticide in its own right.

(4) Dieldrin—a metabolite of the insecticide aldrin and an insecticide in its own right.

(5) Heptachlor epoxide—a metabolite of the insecticide heptachlor.

(6) BHC, generally in the form of the gamma isomer (Lindane)—an insecticide.

(*b*) Less persistent organochlorine insecticides :

(1) Endrin—an insecticide.

(2) Endosulfan—an insecticide.

All these substances are used in agriculture ; some, notably DDT and dieldrin, are used in the control of disease vectors. DDT and dieldrin are also used industrially for moth-proofing woollen goods etc.

(*c*) Polychlorinated biphenyls (PCBs).

These include a large number of related compounds and metabolites used in the plastics, engineering and electrical industries.

The PCBs were first synthesised in the 1930s and the organochlorine insecticides in the 1940s and 1950s, and their use has greatly increased since those times, so that today some or all of them are probably used in all countries in the world.

The Presence of Organochlorine Insecticides and PCBs in the Marine Environment

Most pesticides break down rapidly into harmless constituents ; the rate depends on the nature of the chemical, climate, soil type etc. If they do not break down quickly they tend to spread outside the areas of application into the surrounding environment ; transport can be in air, in water or in the bodies of animals. Organochlorine insecticides were used for many years before it was fully realised that their special characteristics of persistence and high solubility in fat posed important environmental problems. However, during the early 1960s it became clear that these compounds were present in a wide range of terrestrial, freshwater and marine environments of the U.S.A. and the United Kingdom, and that they tended to accumulate in food chains, so that predatory species on average contained larger amounts of insecticides than did herbivorous ones (Moore and Walker, 1964). Subsequent studies of marine invertebrates, fish, birds and mammals collected from the Irish, North and Baltic seas showed that most specimens contained detectable residues of organochlorine insecticides, notably of DDE and dieldrin (Moore and Tatton, 1965 ; Robinson *et al.*, 1967 ; Jensen *et al.*, 1969).

In 1966 marine pollution by DDT was shown to extend to the remotest areas of the world, for in that year DDT was reported from penguins and other vertebrates in the Antarctic (George and Frear, 1966 ; Sladen *et al.*, 1966). The penguins were collected near a large American base and it was theoretically possible that contamination had resulted from it ; but when DDT, dieldrin, heptachlor epoxide and BHC isomers were detected in penguins, fish and other animals from Signy Island, in a remote and uninhabited part of the Antarctic, it was clear that the presence of organochlorine insecticides in the Antarctic fauna must be due to global movement of air and water and to accumulation (Tatton and Ruzicka, 1967).

Monitoring of organochlorine insecticides in the marine enrivonment was started in Great Britain in 1963 ; the eggs of several species of seabirds which feed entirely on marine fish and marine invertebrates were used. They included fish-feeding terns, auks, cormorants and a mollusc-feeding duck and wader (Moore and Tatton, 1965 ; Anon. 1969). All the eggs so far analysed have contained residues of DDE and dieldrin, mostly within the range of 0.4 to 3.5 parts per million of total insecticide residue. DDE levels have remained constant in most localities but there is some indication of a decline in dieldrin levels following restrictions on the use of this substance and of aldrin in recent years.

A much more extensive monitoring system using oysters was initiated by the United States Department of the Interior in 1965, and now involves analyses of animals collected from about 175 stations in estuaries on the Pacific, Atlantic and Gulf of Mexico coasts of the United States. The results indicate widespread contamination of United States estuaries by organochlorine insecticides (Butler, 1969).

In the course of these and other investigations, other chlorinated substances were detected during analysis by gas-liquid chromatography. In 1966 Jensen identified them as polychlorinated biphenyls. Studies of these compounds showed that they, like the organochlorine insecticides, were widely distributed in the marine evironment (Risebrough *et al.*, 1966 ; Prestt *et al.*, 1970).

The Biological Significance of Organochlorine Insecticides and PCBs in the Marine Environment

Pesticides can affect organisms directly by having lethal or sublethal toxic effects, and indirectly by altering ecological relationships (Moore, 1967). Toxicological experiments show that there are great differences between species in response to the same pesticide. In general, mammals and birds are much more resistant to organochlorine insecticides than are invertebrates. Crustacea are very susceptible to DDT : the LC50/48 hours for the Common Shrimp (*Crangon vulgaris*) is about 0.0033 ppm. (Portmann, 1970). Sublethal effects are obtained at very much lower levels, for example, concentrations of 0.0001 parts per million of DDT markedly affect the growth rate of the oyster (Butler, 1966).

Fish are particularly susceptible to dieldrin, endrin and endosulfan. Concentrations as low as 0.00002 parts per million of endosulfan can cause death.

Serious casualties to fish and fish-feeding birds have been caused by accidental spillages of insecticides into water. For example, an estimated 40 million fish were killed when some endosulfan was spilled into the River Rhine in Germany in 1969. Effluent from a pesticide factory on the same river was the indirect cause of a high mortality of fish-feeding seabirds nesting on a coastal island many miles from the mouth of the river (Koeman, 1967).

Very few studies have been made of the biological effects of background environmental pollution by pesticides in the sea. However, there is strong circumstantial evidence that the recent declines in breeding success of the Bermuda Petrel (*Pterodroma cahow*) in the west Atlantic is due to DDT contamination. This rare bird species feeds on planktonic animals in the open sea and the specimens analysed contained unusually large residues of DDT (Wurster and Wingate, 1968). The thinning of eggshells of many species of birds which contained more than average amounts of organochlorine insecticides is also almost certainly a sublethal effect of organochlorine insecticides. This effect has been observed in some marine species as well as in terrestrial and freshwater ones (Ratcliffe, 1970). Concentrations of organochlorine insecticides in marine crustacea from European waters suggest that local populations of these animals could be at risk from organochlorine insecticides, but little is known about their populations and so the biological significance of pesticide pollution cannot be assessed.

Conclusions and Discussion

Very little is known about the effects of persistent organochlorine insecticides on marine species, but it is now clear that many marine environments throughout the world contain organochlorine insecticides and PCBs. While concentrations in water may be very small and even below the limit of detection, these substances can become accumulated in invertebrates, fish and fish-feeding birds and mammals to levels which could have biological significance, especially to very sensitive organisms (e.g. crustacea and young fish) and to predators at the ends of food chains. Therefore, all concerned with the resources of the seas should be aware of the potential dangers of persistent organochlorine insecticides and PCBs. These substances are of great value to mankind in combating disease, for increasing food production, and in industry, but it is also obvious that they are inherently hazardous substances and so great care should be taken to prevent undue contamination of freshwater, and hence the sea, by them. Special care should be taken to prevent the contamination of water by the insecticides endrin, endosulfan, dieldrin and aldrin as these are exceptionally hazardous to fish. Bearing these facts in mind, organochlorine insecticides should be used as sparingly as possible and the recommended application rates should never be exceeded. Great care should be taken to prevent concentrated material entering ditches, streams, rivers and lakes ; disused containers should not be dumped in water, nor should spraying equipment be cleaned in it. Authorities should ensure that the effluents of factories making or using organochlorine insecticides and PCBs do not enter rivers or the sea, and should make certain that wastes containing these compounds are not dumped from ships. If all these precautions are taken, the environmental hazards of organochlorine insecticides and PCBs should be reduced until such time as they can be replaced by compounds which are less persistent and so less hazardous to the environment.

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