Interactions of PCBs, DDT and DDE in a Marine Diatom

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A factor often overlooked in assessing the environmental effects of toxic substances is that organisms in nature are frequently exposed to several toxicants simultaneously. Because of their ubiquity, chlorinated hydrocarbons, in particular, are usually co-contaminants in the environment and biota. Thus PCBs (polychlorinated biphenyls), DDT [1, 1, 1-trichloro-2, 2-bis (p-chlorophenyl) ethane], and DDE [1, 1-dichloro-2, 2-bis (p-chlorophenyl) ethylene] are found together in the tissues of many species from both terrestrial and aquatic habitats (RISEBROUGH et al. 1968; JENSEN et al. 1969; PRESTT et al. 1970; HAYS and RISEBROUGH 1972).

Information on how these substances may interact is scant. The interactions of some organochlorines have been considered in attempts to maximize insecticidal action (HEWLETT 1960). PCBs increased or decreased the toxicities of DDT and dieldrin to flies, depending on the extent of chlorination of the PCBs and the species of fly (LICHTENSTEIN et al. 1969). DDT decreased dieldrin storage in rats by inducing enzymes that hydroxylated the dieldrin, increasing its excretion (STREET and CHADWICK 1967; CONNEY and BURNS 1972). We report here studies on interactions among PCBs, DDT and DDE in a marine diatom known from previous studies to be sensitive to DDT and PCBs individually (MOSSER et al. 1972a).

Materials and Methods

Thalassiosira pseudonana (strain 3H) [formerly Cyclotella nana (HASLE and HEIMDAHL 1970)] was grown axenically at 23-24°C in half-strength "f-1" medium (GUILLARD and RYTHER 1962) supplemented with 200 mg $NaHCO_3$ per liter and containing Instant Ocean (Aquarium Systems, Eastlake, Ohio) adjusted to a salinity of 25 parts per thousand in place of natural seawater. Cultures were illuminated with 7500 to 8600 lumens per square meter from cool white fluorescent lamps and growth was monitored with a Coulter counter. The chlorinated hydrocarbons

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were dissolved in methanol and diluted 10,000-fold into cultures containing 10^4 exponentially growing cells per milliliter. Control cultures received equal volumes of methanol. DDT and DDE (both 99.9% pure) were gifts of the Geigy Chemical Company, Ardsley, N.Y. The PCB preparation was Aroclor 1254 provided by the Patuxent Wildlife Research Center, Laurel, Md.

Results

DDE and DDT interacted quite differently with PCBs. DDE was synergistic with PCBs; growth inhibition by 10 parts per billion (ppb) PCBs or 100 ppb DDE was minor, whereas these substances together at these concentrations inhibited growth substantially (Fig. 1A). Higher concentrations of either substance caused a still greater growth inhibition.

By contrast, DDT counteracted the toxicity of PCBs. Treatment with 50 ppb PCBs alone almost stopped growth, but simultaneous treatment with 50 ppb PCBs and 500 ppb DDT restored the growth rate to about two-thirds that in control cultures (Fig. 1B). Lower concentrations of DDT counteracted PCB toxicity to a lesser extent. DDT added 12 or 24 hours after PCB treatment also reversed inhibition by PCBs (Fig. 1B).

Since reversal occurred even after inhibition by PCBs had been fully manifested, the counteraction of PCB toxicity by DDT evidently involved an intracellular interaction, rather than physical protection from PCBs such as by coprecipitation of these water-insoluble substances from the growth medium. Counteraction could result from DDT-induced elimination of PCBs, analogous to DDT-induced dieldrin elimination in the rat (STREET and CHADWICK 1967; CONNEY and BURNS 1972), or by displacement of the PCBs from a sensitive cellular site.

Interaction between DDT and DDE was only slight. Growth inhibition caused by treatment with 500 ppb each of DDT and DDE was intermediate between that caused by 500 ppb of either of these substances alone (Fig. 1C).

Discussion

DDE, a dehydrochlorinated metabolite of DDT, is a principal chlorinated hydrocarbon pollutant in the environment (RISEBROUGH et al. 1968; JENSEN et al. 1969; PRESTT et al. 1970; HAYS and RISEBROUGH 1972). DDT is converted to DDE abiotically, by microorganisms, and by many animals, including man (O'BRIEN 1967; MENZIE 1969). The very different interactions of DDT and DDE with PCBs suggest, however, that *T. pseudonana* did not carry out this conversion to an appreciable extent. Because it is not insecticidal, DDE is often considered a "detoxified" form of DDT, but it is nevertheless

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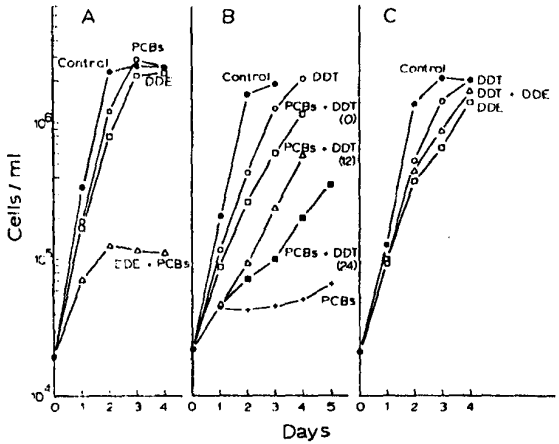

Fig. 1. Interactions among PCBs, DDE and DDT in T. pseudonana. Organochlorine concentrations were, in A, 10 ppb PCBs and 100 ppb DDE; in B, 50 ppb PCBs and 500 ppb DDT; in C, 500 ppb for both DDE and DDT. Time, in hours, of DDT addition to PCB-treated cultures is shown in part B. Experimental points are means from triplicate cultures. Significance of differences between mean values was determined by the least significant difference test performed on log-transformed data (SOKAL and ROHLF 1969): A. Cultures treated simultaneously with PCBs and DDE differed significantly from all other cultures ($P<.001$ at 3 days). B. Cultures treated with both DDT and PCBs differed from those treated only with PCBs (at 3 days, $P<.001$ for DDT added at 0 time, $P<.01$ for DDT added at 12 hr, and $P<.05$ for DDT added at 24 hr). C. Cultures treated simultaneously with DDT and DDE differed from those treated with these substances individually ($P<.05$ at 3 days).

toxic to some organisms. DDE interferes with avian reproductive physiology (BITMAN et al. 1970; PEAKALL 1970; OESTREICHER et al. 1971; WIEMEYER and PORTER 1970), and it is more toxic than DDT to T. pseudonana.

Competition between sensitive and resistant species (MOSSER et al. 1972b) and environmental conditions such as

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temperature (FISHER and WURSTER 1973) can affect the toxicity of organochlorines to phytoplankton. This study indicates that interaction among organochlorines must also be considered in evaluating the effects of these substances; DDE and PCBs may have greater environmental impact together than would be expected from separate toxicity tests. These interactions could not have been predicted from knowledge of their isolated behavior, chemical structures or properties. Our results with these chlorinated hydrocarbons illustrate the myriad of unforeseeable synergistic interactions possible among the many toxic pollutants in the environment.

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