Oceans as alphabet soup: Focus on DDT and PCB's

Recent studies throw new light on the distribution and pathways of DDT and PCB's in the oceans

by Richard H. Gilluly

It is possible that DDT does not harm humans directly in the quantities that exist in the environment—although the question is still open. Recently there have come forward defenders of DDT ranging from Nobel laureate Norman E. Borlaug to a Los Angeles couple who swallowed large quantities of the insecticide and said they were not harmed. As Borlaug says, DDT has been important in reducing disease and increasing food production in underdeveloped countries. On the other hand, as Dr. Barry Commoner of Washington University in St. Louis points out, second and third order effects may cancel the apparent gains.

But the view that if DDT in environmental amounts cannot be proven to be harmful to humans it is therefore safe, cannot be sustained. There is no doubt whatever that it harms other organisms and thus "poses an imminent threat to human welfare in terms of maintaining healthy, desirable flora and fauna in man's environment," in the words of a report by a scientific advisory panel to the Environmental Protection Agency.

Biological scientists are constantly producing new evidence of the widespread dissemination of DDT and its metabolites in various ecosystems and of its harm to organisms in these systems. Scientists at Woods Hole Oceanographic Institution recently released new evidence regarding the occurrence of DDT, as well as of the ubiquitous industrial compounds, polychlorinated biphenyls (PCB's), in marine organisms, and the results are no cause for optimism. "PCB," say the scientists, "is readily demonstrable in all, and DDT in most of a series of organisms collected from the North Atlantic Ocean." And, they add, ". . . We believe some of the high concentrations we have found in open-ocean organisms to be real cause for concern."

The scientists are George R. Harvey, Vaughan T. Bowen, Richard H. Backus and George D. Grice. They collected a variety of marine organisms on cruises in the Atlantic during the past year under a National Science Foundation grant. "It was our intention," they say in a paper delivered in August at a Nobel symposium in Gothenburg, Sweden, "to look for gradients of [PCB and DDT] concentrations in reference to a few major features, such as river-borne supplies to the Hudson and Savannah estuaries, the southward transport in the Canaries Current of European petroleum [DDT and PCB are highly soluble in fats and oils], trade-wind transport to the North Equatorial Current, the gyral circulation of the Sargasso Sea, and the large currents of the South Atlantic." Organisms were collected by trawls, nets, hook and line.

To understand the significance of the work, it is necessary to have some understanding of the immensely complicated, and often not yet fully explained, pathways of transmittal of DDT in the environment, in both living and nonliving systems. DDT's danger to living organisms comes from its near insolubility in water and its relatively high solubility in fats and oils, including the lipids of the living organisms—plus, of course, its persistence. "The physical and chemical characteristics of DDT might lead one to assume that the biosphere should behave as a giant separatory funnel, gradually partitioning the lipid-soluble residues into the lipid-rich biota," explains an article in the Dec. 10 SCIENCE written by George M. Woodwell, Paul P. Craig and Horton A. Johnson of Brookhaven National Laboratory.

Fortunately, continue the same authors, the partitioning of DDT in the fatty tissues of organisms has not occurred to the degree that would be expected on a worldwide basis, and thus there have not been the massive extinctions of organisms that might likewise have been expected. The authors add, however, that the difficulties in measuring effects are so great that it is likely that long-term chronic effects have been overlooked.

But there is no doubt, they continue, that DDT has posed large dangers to organisms in local situations, particularly warm-blooded, small-bodied carnivores. Ospreys, pelicans and other bird species have experienced severe disturbances in reproduction, and their numbers have thus declined in these local situations. But the declines can be arrested or reversed relatively quickly when DDT use is halted in the affected local area. This fairly simple relationship between amounts of DDT placed in a local environment and its levels in and effects on organisms is direct and not difficult to understand, particularly in aquatic environments where environmental amounts of DDT and amounts in organisms are clearly correlated. But the problem grows far more complicated when DDT is considered on a worldwide basis.

For one thing, it is increasingly obvious that DDT transport into oceans via rivers is less significant than earlier thought. Evidence now indicates that much of the DDT sprayed on crops never reaches the land surface but instead enters the atmosphere. And DDT that does reach the land surface often vaporizes and is carried away in the atmosphere. The pathway for DDT worldwide appears, say the Brookhaven authors, to be "from the land, through the atmosphere into the oceans and [ultimately] into the oceanic abyss." Biologically, the pathway appears to be from simpler organisms up the food chain to more complex organisms—with a magnification taking place between each trophic level (that is, each level of the food chain).

What the Woods Hole work reveals is that both the physical and biological mechanisms are highly complicated and do not always follow the general patterns with precision. Further, the new work indicates the PCB's, although chemically similar to DDT, may often take different physical and biological routes than DDT. Finally, the work throws some new light on the question —outlined by the Brookhaven researchers—of why DDT levels in the environment are high enough to cause large-scale extinctions (if the "separatory funnel" effect of concentration in lipids is fully operative) but do not, in fact, do so. (This, however, only mitigates the hazards of DDT in the oceans. The Brookhaven authors suggest there are probable ill effects short of extinction, and the organism levels discovered by the Woods Hole researchers tend to corroborate this.)

The Woods Hole researchers say that a possible speedup of both DDT and PCB disposal to the abyssal "sink"—where biological effects are minimal—may occur biologically. "A group of fish and crustacea which feed near the sea surface at night but migrate to considerable depths during the day show DDT and PCB concentrations not greatly different from those of predaceous organisms whose lives are spent mostly in the upper layers," they say. "We believe this shows that biological removal processes may help to control chlorinated hydrocarbon concentrations in the open ocean." In short, there may be biological mechanisms which rather quickly take DDT and PCB's from the air-water interface or from oily slicks on the surface to great depths—thus preventing magnification to a point where extinctions would occur in the more biologically active upper levels of oceans. The Woods Hole researchers now plan analysis of sediment cores, already collected, "to estimate how effective the biological process is in removing these toxic materials from the whole water column."

The Woods Hole work shows there are apparently no consistent lateral gradients of DDT or PCB distribution in the Atlantic Ocean—except in local situations, such as off the coast of Bermuda—thus indicating that large amounts are not coming from estuaries. And there seems to be no indication of a systematic pattern of DDT to PCB ratios conforming to relative amounts released from Europe and North America (the ratio of PCB to DDT from European sources being higher than the North American ratio). The apparent explanation for these findings is the earlier mentioned airborne transport of both substances and a general mixing. However, earlier work indicated that DDT and PCB's are transported in the atmosphere in different physical states, DDT attached to dust particles and PCB's as a vapor. The Woods Hole scientists plan measurements of ratios in prevailing winds from Europe and North America, which may establish whether these two modes of atmospheric conveyance do indeed operate to bring DDT and PCB's into the oceans.

Other findings by the Woods Hole scientists indicate that while there is a general pattern of both DDT and PCB concentration up food chains, there are exceptions to this, as well as differences in pathways for the two kinds of compounds. For instance, certain phytoplankton samples showed higher DDT than PCB concentrations in areas of petroleum residues—indicating these residues may be intermediating in the uptake of DDT but not of PCB's. A tendency to high PCB and low DDT in some zooplankton samples may not be related to the diets of the organisms, but rather to surface/volume ratios of the animals. Thus, for some reason the zooplankton may absorb and/or retain PCB's directly from the water, but may reject DDT by this route, or not retain it. A related hypothesis, one which the Woods Hole scientists lean toward, is that the zooplankton samples, collected at night, may have been heavily weighted with vertically migrating organisms. According to the hypothesis, these organisms may quickly have absorbed ambient PCB's through surface uptake when they came to upper layers for nighttime feeding, but had not yet had time to ingest high levels of DDT when captured.

These are just a few of the complexities and unanswered questions revealed by the Woods Hole scientists, and analysis of data is still going on. Dr. Bowen, in an interview with SCIENCE NEWS, talked about some of the difficulties. Concentration of chlorinated hydrocarbons up the food chains of land animals is relatively straightforward, because the food pathway is the most significant one in these organisms. "But the non-food-drink pathway for aquatic creatures is unavoidably more significant," says Dr. Bowen. That is, the environment-organism interface is far more blurred for the aquatic creatures than for terrestrial ones, for which the boundaries are clear-cut.

And there are some scientists who believe food-chain amplification of the toxic materials is relatively insignificant in aquatic organisms. Although Dr. Bowen does not agree, he says there is no doubt there are other factors at work. For instance, levels may be related simply to size and life-span of the organism. A large, long-lived fish may have more DDT and PCB's in its body than a smaller, shorter-lived one.

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And aquatic food chains are more often "short-circuited" than dry-land ones. "Tuna, sometimes when they just seem to be feeling good, will fill their stomachs with medium-size grazing plankton instead of with larger predaceous fish," says Dr. Bowen. How often, and in how many species, such short-circuiting occurs just is not known yet.

But probably the most important need is for toxicological work. Marine creatures are notoriously difficult to maintain in the laboratory. "A variety of organisms we collected," says Dr. Bowen, "had levels of DDT and PCB's in the same range that has been established to be toxic to freshwater organisms. Desperately needed is a study of physiological, genetic and cytomorphological effects in marine organisms. It just isn't being done."

And PCB's, only recently recognized as major environmental pollutants, are far less understood than DDT. Little is known of their metabolism, and their persistence in nature is expected to be longer than that of DDT—which scientists generally agree has a half-life of 10 years.

The implications are serious. A model constructed by the Brookhaven authors indicates that DDT levels worldwide will soon be in a decline if there is decreasing use through 1974, with levels back to the pre-1950 level by the year 2000. Sheer luck, say these authors, saved the world from massive organism extinctions due to DDT. The reason for this luck is not yet explained, although the Woods Hole work indicates the fairly rapid biological transport to abyssal sediments may be at least part of the explanation. Although the use of DDT in the United States has been steadily declining since 1960, high levels of use in foreign countries could continue; if so, levels in the mixed layers of the oceans, the troposphere and the biota will continue to rise, say the Brookhaven scientists.

The Woods Hole work indicates, at the least, that there are significant differences between PCB's and DDT in their respective physical and biological pathways. There are probably also differences in metabolism and persistence. Although PCB use in the United States has been curtailed, this may not be the case in other nations. So little is known of PCB's that the outcome of their dissemination is difficult to predict. Once again, luck may not hold.

There are several things that must be done. One is to quickly adopt international inventory, monitoring and control systems for toxic chemicals, as recommended in a variety of recent reports, including the Study of Critical Environmental Problems (SN: 10/31/70, p. 344) and the more recent Institute of Ecology report (SN: 12/18/71, p. 410). Another is to evolve mechanisms whereby developed nations help underdeveloped nations, perhaps through subsidies, to begin coping with their pest problems with a whole range of techniques relatively more expensive than persistent, broad-spectrum chemicals, and thus to eliminate objections such as Borlaug's to the halting of DDT use. Finally, far more research and development must be done—so man can learn what he has done to the biosphere already with the persistent chemicals, how he can halt or reverse the undesirable changes and what he can do to handle pest problems in less damaging ways in the future. □