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Opponents Call It Danger to Environment; Killer of Many Life Forms

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DURING the past quarter-century, man has subjected his environment to an increasing variety of chemical insults in the form of pollutants with molecular structures never before encountered by living organisms. Of these contaminants, the chlorinated hydrocarbon insecticides (those, such as DDT, that contain chlorine, carbon, and hydrogen) are probably more widely distributed than any other synthetic chemicals and have become one of the world's most serious pollution problems.

Residues of DDT and some of its relatives seem to be almost everywhere—in soils never treated with the chemicals, in birds and seals that never leave the Antarctic (although DDT has never been used on that continent), in most other animals and probably all humans, in the air, even in remote parts of the world, and even in the rain. Yet, after 25 years of use, the physiological mechanism of action for the chlorinated hydrocarbons is poorly understood, and we are only now discovering some of its environmental effects. We are, in a sense, conducting a biological experiment of colossal proportions, using the entire world as a laboratory.

How will it all come out? No one knows. Clearly some parts of the experiment have gone sour, and the flow of bad news increases as the data come in. Not all is mystery about these chemicals, however, for there is a great deal we do know about them.

DDT was first made in 1874, but its insecticidal properties were not discovered until World War II. With a high toxicity, great persistence, and side effects that were neither of concern nor well understood at the time, DDT was the miracle insecticide that played a heroic and glamorous role in the war, saving thousands of lives that would otherwise have been lost to malaria, typhus, and other insect-borne diseases. After the war it became a panacea for all insect problems, and its usage was greatly expanded.

While DDT has been the most widely used and extensively studied, and its residues are the most widespread within the environment, most other chlorinated hydrocarbons have similar properties and should be expected to have comparable ecological effects. These include dieldrin, aldrin, endrin, heptachlor, chlordane, lindane, and others commonly used against insects under a host of circumstances, including gardens, farms, and forests.

Properties Cause Unique Problems

In order to understand the movement and consequences of these materials within the natural environment, it is first necessary to know something of their properties. The chlorinated hydrocarbons present a relatively unique environmental problem because they combine four important characteristics in the same molecule:

1 Broad Toxicity and Biological Activity—Rather than having a toxic action that is limited to insects, as is popularly supposed, the chlorinated hydrocarbons are toxic to a broad spectrum of living organisms, including most of the animal kingdom and all vertebrates. All are nerve poisons. They cause instability or spontaneous "firing" of nerve cells, and increased doses result in tremors or convulsions — typical symptoms of acute poisoning that can occur in organisms ranging from houseflies to man. In general, if an organism has nerves, the chlorinated hydrocarbons can kill it.

Recent studies have uncovered other, more subtle, yet probably more important, mechanisms of action. At sublethal concentrations, organisms show increased nervousness, hyperactivity, and various behavioral abnormalities. We now know that most chlorinated hydrocarbons are enzyme inducers, i.e., they can induce enzymes in the liver that modify the steroid sex hormones, thus changing their biological activity and affecting vital physiological processes. At the same time, some members of the DDT family can function as estrogens, thus perhaps further upsetting hormone balance. Very recent work now suggests that DDT may inhibit carbohydrate metabolism, that it may affect the genetic material to influence future generations, and that it may be carcinogenic; each of these mechanisms needs further research.

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DDT Is 'Compound of Extinction'

Falcon, Eagle Decline Blamed on Variation of DD

DDT Harm to Trout Claimed

UW Wildlife Expert Links DDT With Decline of Birds

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2 **Mobility**—Unfortunately, these insecticides do not remain where they are applied, dispersal through the environment being facilitated by a variety of transport mechanisms. Obviously the chemicals can travel about within living, mobile organisms, though this mode of transport seems minor. Despite low water solubilities and vapor pressures, large amounts can be carried by vast quantities of moving water and air, and dispersal is further facilitated by the tendency of these materials to form suspensions in both air and water. Since many insecticide application procedures intentionally produce atomized droplets or particles, substantial amounts are thereby passed into the atmosphere. Less than half the amount sprayed from a plane may reach the ground. Once in the air, these materials can circle the globe in a few weeks; fallout from the air probably contributes about the same quantity of pesticides to the oceans as do major river systems.

The chlorinated hydrocarbons also readily adsorb to particulate matter like soil particles, which are carried away by wind and water. Escape into the air is further aided by the process of codistillation, whereby the chemicals pass into the vapor state associated with evaporating water. Thus a wet field will release pesticides into the air much more rapidly than will a dry one. It is clear, then, that these insecticides can be transported about much of the earth to points far distant from the original application site by currents of water and air, as well as by mobile organisms.

3 **Chemical Stability**—In the environment, the chlorinated hydrocarbons are very stable compounds; they probably have a half-life of many years or decades, but exactly how long they persist we do not know. Mechanisms for effectively metabolizing or breaking down these exotic materials apparently have not evolved, although certain tissues, particularly liver, can bring about gradual breakdown. DDT is slowly metabolized into DDE, DDD, and eventually other compounds, but unfortunately most of these, too, are toxic and induce liver enzymes. DDE, apparently more stable than DDT, is probably the world's most widely distributed synthetic organic chemical.

Treated areas show declining residues during subsequent years, but this "disappearance" is sometimes falsely equated with decomposition. The two are not the same. Increasing evidence indicates that much of these materials have simply gone elsewhere in their original, or slightly modified, form, retaining their biological activity.

4 **Solubility Characteristics**—DDT is insoluble in water—almost. DDT saturates water at only 1.2 parts per billion (ppb), making it one of the most insoluble organic substances known. Conversely, the chlorinated hydrocarbons are soluble in lipids (fats or fat-like materials). They are, therefore, invariably more soluble in any biological material, living or dead, than in water, since all organisms contain lipids. If we divide the biosphere into the inorganic (nonbiological) and the organic (biological), we must always expect the chlorinated hydrocarbons to flow from the former into the latter. Organisms, therefore, remove these chemicals from their environment and retain them.

DDT Travels Far

These four properties mean that biologically potent chemicals will contaminate non-target organisms far removed by both time and space from the site of application.

Chlorinated hydrocarbons may be absorbed by organisms through the gills, the skin, from the diet, and from the air via the lungs. Muds and other solids that hold these chemicals by absorption serve as reservoirs, feeding the chemicals into the water as they are absorbed by organisms. Living organisms accumulate these residues and become contaminated, often from an environment that may appear relatively "clean." For this reason some measurements of environmental quality are misleading. One must analyze living organisms, rather than water, to monitor water quality. Water and air are the transport media, but they contain only minute amounts of these chemicals.

Biological Concentration Occurs

Once these insecticides get into food chains, something else happens—the phenomenon of biological concentration, often called biological "magnification." Each organism eats many organisms from the next lower trophic level, i.e., the next step down in the food chain. A robin, for example, eats many earthworms, and a large fish eats many smaller fish. These food organisms are digested and excreted, but the chlorinated hydrocarbons are retained. The chemicals remain in biological material and therefore accumulate, the concentration depending on rates of intake, breakdown, and excretion.

The use of DDT in attempted control of Dutch elm disease is a clear and relatively simple example of food chain contamination. Since DDT is sprayed when the elms are leafless, only a small fraction remains on the trees. The rest is either lost into the air or settles to the earth. That retained by the tree eventually also reaches the ground. Earthworms and other organisms that work the soil accumulate the DDT and become contaminated. Many species of ground-feeding birds eat the soil organisms, concentrate the DDT further, receive a lethal dose, and die with tremors.

Flying insects also become contaminated by contact with the trees and soil, especially those emerging from soil dwelling larvae. Insectivorous birds of the treetops thereby also become involved in this mass avian mortality. In some treated areas, robin mortality has been virtually complete and birds of all species have been reduced by as much as 90 percent.

Wide areas of the coniferous for-

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ests of North America have been sprayed with DDT during the past decade to control the spruce budworm. In New Brunswick, Canada, where excellent salmon streams include the Miramichi River, DDT applications have caused severe and widespread losses of salmon, trout, and other fish. After an application of DDT in 1954, not a single salmon fry was seen that year. Harmful effects extended 30 or more miles below the spray zones and lasted for several years. And effects were not limited to fish. A single treatment changed the insect ecology of the area for at least three to four years.

Concentrations Eventually Kill

Since the chlorinated hydrocarbons are concentrated as they ascend the food chain, carnivorous birds at the top of this pyramid reach the highest concentrations and face special problems. Death sometimes occurs.

In North America, reproductive success of the osprey has declined sharply. A colony in Connecticut, its habitat and other factors apparently unchanged, declined from 200 pairs in 1938 to 12 pairs in 1965. Their eggs contained 5.1 parts per million (ppm) of DDT residues and productivity was 0.5 young per nest, while Maryland birds with 3.0 ppm produced 1.1 young per nest and normal productivity was 2.2 to 2.5 per nest. Ospreys are fish-hawks and DDT residues in the fish eaten by Connecticut ospreys proved to be five to ten times higher than in the food of the Maryland birds.

Studies of the peregrine falcon in Europe reveal a widespread and rapid population decline which began during the early 1950's. The decline was characterized by egg breakage and egg eating by parent birds, abandonment of nests, and other abnormal breeding behavior, and it coincided geographically and in time with the use of chlorinated hydrocarbon insecticides. Tissues and eggs of the peregrine contained DDE, dieldrin, and heptachlor epoxide.

A highly significant, sudden, and widespread decrease in eggshell thickness and calcium content occurred during 1946-48 in several British birds of prey, including the peregrine falcon. Shell thickness and calcium content were stable from 1900 to 1946, then declined by 7 to 25 percent within a few years with no subsequent recovery. The years of decline coincided exactly with the introduction of DDT into the world environment.

DDT Biological Makeup

But what do eggshells have to do with DDT and reproduction? Quite a lot. In birds, increased absorption of calcium from the diet, decreased excretion, and deposition of calcium in bone marrow are all mediated by estrogen, a steroid sex hormone. The calcium in the marrow is later transported to the oviduct where it becomes part of the eggshell. A subnormal estrogen level interrupts this crucial chain of events in the reproductive cycle.

Recent studies showed that DDT, DDE, and dieldrin induced liver enzymes to break down steroid sex hormones in pigeons, and caused mallards and sparrow hawks to lay thin-shelled eggs and have a lower reproductive success.

In aquatic environments, the chlorinated hydrocarbons may contaminate virtually all organisms at all levels of the food pyramid. This has happened to the Lake Michigan ecosystem. DDT residues in bottom muds averaged 0.014 ppm, but amphipods contained 0.41 ppm, nearly 30 times that of the mud. Several species of fish carried residues 10 times higher than the amphipods, and herring gulls at 99 ppm were 20 to 30 times more than the fish. The gulls showed low breeding success and behavioral abnormalities, and could not withstand stress. When starved, the birds developed tremors and died of DDT poisoning while less contaminated gulls easily withstood the same treatment. (Starvation depletes fat reserves that store DDT residues, thus releasing the toxins into vital tissues.)

Fish Accumulate Residues

The Coho salmon, being a top carnivore, also accumulated residues in Lake Michigan and these were passed into the eggs. Recently almost 700,000 salmon fry died shortly after hatching. The fry were poisoned by residues in the egg yolk during final absorption of the yolk sac. Heavy mortality of trout fry occurred similarly in several New York lakes. For several years, mortality of fry from Lake George was 100 percent.

Clear Lake, California, offers another classic example of biological concentration in action. Additions of DDT to the war in an attempt to control gnats, the last in 1957, were followed by the dying of western grebes, reduction of the nesting colony from 1,000 to 30 pairs by 1960, complete nesting failure among survivors for several years, and 500 to 1,500 ppm of DDD in grebe fat. In 1967, ten years after the last treatment, the grebes still averaged 544 ppm of DDD in their fat, and the colony of 165 pairs still had very poor nesting success.

Effects are by no means limited to the top of the food pyramid. A few ppm of DDT in the water can decrease photosynthesis in marine phytoplankton. These single-celled algae are the indispensible base of marine food chains and are responsible for more than half of the world's photosynthesis. Interference with this process could have profound worldwide biological implications.

The nature and movement of the chlorinated hydrocarbons indicate that they will be transferred from the earth's treated land areas to its ocean basins, where they will accumulate. Being so insoluble in water, however, we cannot expect them to "get lost" in the oceans; they will be picked up by its living organisms. Recent analyses of fish and birds from both the Atlantic and Pacific Oceans indicate that this process is occurring.

The Bermuda petrel is a rare oceanic bird of the North Atlantic that has no contact with any continent or area treated with insecticides. Yet its eggs and chicks average 6.4 ppm of DDT residues, and reproductive success has declined significantly since 1958. Only from its oceanic food chain could this bird become so contaminated.

There are more data from the Pacific, but the story is the same.

Clearly the chlorinated hydrocarbon insecticides cannot continue to be used in the natural environment without serious degradation of the world ecosystem. Fortunately we have a choice. Many biological techniques exist for controlling insect populations, and numerous other less stable, more specific insecticides are available. These alternatives are highly effective. Man's control of pests requires ecological sanity. Which way will we go?