Risebrough, R. & Brodine, V. (1970): More Letters in the Wind. – Environ. Sci. Policy Sustain. Dev., 12(1):16-26, 6 Abb., 2 Tab.; doi:10.1080/00139157.1970.9932353.

MORE LETTER

IN THE ALPHABET of environmental contamination, PCB may become as well known as DDT, and for some of the same reasons. Like DDT, PCB contains chlorine, hydrogen and carbon; like DDT, it is not soluble in water, it is soluble in fat, and it is extremely persistent in the environment.

The chemical similarity between the two also suggests similar physiological effects in the bodies of fish, birds, and perhaps people. In one particular respect which will be discussed later, this has been confirmed in the laboratory.

A striking difference is that DDT has been used in the open environment with *intent,* because of its toxic effects, to destroy insects; PCB, although known to be toxic, has been used for its other qualities, and has escaped into the environment by *accident.* It is not yet known exactly how and where this happens, nor how much is escaping.

Polychlorinated biphenyls, to give PCBs their proper name, are chemical compounds manufactured in this country by the Monsanto Chemical Company and in Europe and Japan by other manufacturers. A Monsanto spokesman says that PCBs were first produced in 1929 by the Swan Corporation which later became part of the Monsanto Company, and that European production followed, probably about ten years later. Aroclor (the Monsanto trade name) began to be used extensively during World War II.

PCBs have a wide variety of uses. Production and sales figures are not available, but a Monsanto bulletin lists many products in which PCBs may be used as plasticizers, flame retardants, insulating fluids, or to impart some other useful quality. Among these products are natural and synthetic rubber, electrical products, floor tile, printer's ink, coatings for paper and fabric, brake linings, automobile-body sealants, paints, varnishes, waxes, asphalt, and many kinds of adhesives and resins. PCBs are also recommended by Monsanto for mixing with chlorinated insecticides to suppress their vaporization and extend their "kill-life."

The amounts being used are suggested by the fact that PCBs are available in containers ranging from 50-pound cans to 600-pound steel drums and by the tank carload.

As with many of the chemical compounds so widely used in this age of synthetics, concern about the hazards of PCBs has been limited to the possible exposure of industrial workers. Until 1966 it did not occur to anyone to ask whether PCBs might be released into the environment, or if they were, what they might do to birds or fish or human beings.

The first revelation that these compounds had been dispersed in ways which made them available to living things came in 1966 with a report by Soren Jensen, a Swedish scientist, that he had identified

By Robert Risebrough with Virginia Brodine

S IN THE WIND

PCBs in the bodies of 200 pike (taken from different parts of Sweden), in other fish, and in an eagle. Dr. Jensen had also analyzed eagle feathers which had been preserved in a museum, some of them going back as far as 1880; he found PCBs first in feathers collected in 1944.

A colleague of Dr. Jensen, Gunnar Widmark, reported later in 1966 to an international commission studying pesticide analysis. One of the problems in isolating and identifying residues of DDT had been the presence of what Dr. Widmark described as "unknown but chlorine-containing compounds" so similar to DDT that they may sometimes have been mistaken for it. These compounds he and Dr. Jensen had identified as PCBs. The polychlorinated biphenyls had been found in fish and sea birds, in conifer needles, and in some samples of human fat.

Scientists in Britain and the Netherlands have now identified PCBs in wildlife of their respective countries. Jensen and his colleagues have recently reported details of their analysis of Swedish wildlife.

The detection of PCBs in North America began in the spring of 1967 when Monte Kirven of the San Diego Natural History Museum was searching the southwest for peregrine falcons, those swift-flying and now fast-disappearing birds of prey. He found a nest with a single, unhatched, abandoned egg and brought it to our laboratory at the Institute of Marine Resources, University of California in Berkeley. The egg was found to contain five milligrams of DDE, the DDT compound that is apparently the most abundant synthetic pollutant in the environment. The analysis also showed the presence of other compounds which could not be identified. These same compounds had been evident in the analysis of other species of birds and of fish. Because of the importance of the peregrine, an attempt was then made to identify the compounds, but without success until the Swedish papers came to the senior author's attention. With this clue, further work in his laboratory made it clear that the hitherto unknown compounds were polychlorinated biphenyls.

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The Monsanto Company, according to a statement supplied by the company and printed in full on pages 26 and 27, is not yet ready to accept the conclusion that the formerly unknown chlorinated compounds are indeed PCBs. However, because similar results were obtained independently in the laboratories of Sweden, England, Scotland, the Netherlands, and the United States, supported by detailed descriptions of the analytical techniques used (in-

TABLE 1

DDT and PCB in Peregrine Falcons

	Total DDT**	PCB	Ratio of DDT to PCB
Immature bird, California			
breast muscle (wet)*	14.4	9.4	1.5
liver (wet)	7.7	4.5	1.7
brain (wet)	2.8	1.5	1.9
brain (lipid)	36	19.3	1.8
carcass (wet)	20.2	10.8	1.9
carcass (lipid)	300	160	1.9
Adult bird, California			
breast muscle (wet)	127	98	1.3
liver (wet)	77	57	1.4
brain (wet)	49.5	34.6	1.4
brain (lipid)	595	415	1.4
carcass (wet)	85	65	1.3
carcass (lipid)	2,600	1,980	1.3
Immature bird, Arctic			
breast muscle (wet)	2.3	0.16	14
breast muscle (dry)	7.8	0.54	14
liver (wet)	1.0	0.10	10
brain (wet)	0.43	0.037	12
body fat (wet)	50.3	3.2	16
carcass (wet)	9.3	0.80	12
carcass (lipid)	63.7	5.5	12
Second year bird, Arctic			
breast muscle (wet)	99	28	3.5
breast muscle (dry)	296	84	3.5
brain (wet)	85	21	4.7
carcass (wet)	70	19.7	3.5
carcass (lipid)	5,000	1,420	3.5

*Concentrations in parts per million — wet weight, dry weight or lipid (extracted fat) weight.

**Total DDT includes p,p' DDT, p,p' DDE, p,p' DDD, p,p' DDMU, o,p' DDT and o,p' DDE.

Adapted from Risebrough et al., "Polychlorinated Biphenyls in the Global Ecosystem," **Nature** 220 (5172): 1098, Dec. 14, 1968.

cluding mass spectrometry) and the results obtained, this conclusion is now generally accepted in the scientific community. The amounts found, which the Monsanto statement refers to as "in the parts per million range," have been as large as 1,980 parts PCB per million parts of body fat in North American peregrine falcons and 17,000 parts per million in the fat of the white-tailed eagle in Sweden.

The distribution of these compounds is highest in the areas where men are concentrated and carry on industrial activity. They appear in smaller amounts in organisms found at greater distances from urban centers. (See Tables 1 and 2 and the sixth reference under Notes which begins "Jensen. . . .")

The Monsanto bulletin previously mentioned refers to the chemical stability of PCBs and their insolubility in water. These are among the qualities which make them desirable for various industrial uses. They are also among the qualities which make them of great concern as environmental pollutants. Because they have these characteristics, they are extremely persistent — just how persistent is not known — and they can be carried, like DDT, far and wide over the globe by air currents. (DDT is one of the most stable and least water-soluble of the chlorinated hydrocarbon pesticides.)

The PCBs that have already been found in the environment could not all have come from the one insecticide use mentioned in the Monsanto bulletin. There are four other possible sources, all of which should be explored. The first is the stacks of the plants which manufacture Aroclor and the plants which manufacture the products incorporating Aroclor. The second is other forms of industrial waste. For example, PCBs, other synthetics, and oil are mixed to make a fire-resistant hydraulic fluid, one of the "closed system" uses of PCBs referred to in the Monsanto statement. Yet the amount of hydraulic fluid that escapes from this "closed system" is suggested in a Mobil advertisement stating that "industry wastes almost four times as much hydraulic oil as it uses." The third possible source is gradual wear and weathering of Aroclor-containing products which may result in slow release of PCBs as vapor or minute particulate matter into the atmosphere; for example, asphalt which may contain PCBs, is sub-

TABLE 2

PCB Content of Eggs of Sea Birds

Species	Locality	Number of Samples	PBC*
Brandt's Cormorant	Farallon Islands	17	113
Pelagic Cormorant	San Mateo County, Calif.	2	62
Murre	Farallon Islands	6	558
Pigeon Guillemot	Farallon Islands	1	20
	San Mateo County	1	62
Cassin's Auklet	Farallon Islands	2	15
Western Gull	Farallon Islands	1	118
	San Mateo County	1	112
	San Francisco County	1	480
Black-crowned night heron	San Francisco Bay	1	330
	San Francisco Bay	1	24
Caspian Tern	San Francisco Bay	2	805
	San Diego Bay	5	1,010
Forsters Tern	San Diego Bay	2	114
Least Petrel	Baja California	2	3.1
Peregrine Falcon	Baja California	1	471

Where sample included more than one egg, value given is the average.

*In micrograms.


Esther Heacock

Both DDT and PCB affect the hormone systems of birds and rats, and for this reason, may threaten the survival of exposed species such as the least tern shown above with young.

jected to constant friction, and may be a source of either vapor or particulate matter containing PCBs. Fourth, many products containing PCBs eventually wind up in the city dump, where they may be burned. Although fire resistant, at sufficiently high temperatures PCBs may be released as a vapor in the form of highly toxic fumes. (Oxides of PCBs which would be produced in burning are more toxic than the unoxidized PCBs.) PCBs have not yet been detected in samples of airborne particulates, but have been shown to be present in rainwater. More study is obviously needed to show the ways in which PCBs enter the environment.

Evidence of Ubiquity

The worldwide distribution of DDT and related pesticides by a variety of mechanisms, but primarily by air currents, is now known (see "Earth, Air, Water," *Environment,* July-August 1969). Even without knowing the exact sources of PCBs, it would be possible to discover, by the analysis of various forms of wildlife, whether a similar distribution of PCBs is taking place, or whether PCB contamination is local. In the past two years our own work in California, and that of scientists elsewhere in this country, Britain, and Sweden have provided mounting evidence for the worldwide dispersion of PCBs. The levels of PCBs found in wildlife near industrial centers may be very high, frequently higher than the amount of DDT. Birds and fish from more remote areas may contain less PCB than DDT.

In Table 1 the concentrations of DDT and PCB found in various tissues in two peregrine falcons from California and two from the Arctic are shown. The final column shows the ratio of DDT to PCB—in the California birds, between one and two times as much DDT; in the arctic birds, from three-and-a-half to six-

teen times as much DDT as PCB.

The constrast between the immature and the older birds from both areas is also interesting. The immature California bird had 160 parts per million PCB in its carcass lipid (extracted fat), while the adult California bird had 1,980 parts per million. The contrast between the immature and older migrant birds from the Arctic was even greater, with an increase from 5.5 parts per million in the young bird to 1,320 in the older one. The arctic birds migrate through the U.S. and winter in the tropics. Evidently they pick up both DDT and PCB during their migration and on their wintering grounds.

Analyses of Western Gull eggs show that eggs from San Francisco Bay contained more PCB than eggs from the Farallon Islands, 27 miles west of the Golden Gate Bridge, which in turn contained more PCB than eggs from Baja California, a location much further from any industrial center.

Samples of bird tissue and eggs from a variety of species were collected off California (see Table 2). Some of these birds breed in New Zeland and Australia, others on the coasts of British Columbia and Alaska, still others in Alaska and the Canadian Arctic. It is not clear how much DDT and PCB the birds ingested at their native breeding grounds, and how much in the vicinity of California. What is quite clear is that PCB is widely distributed among marine birds which are at the top of a complex mesh of food chains in the sea. One source of PCBs in the birds is clearly the fish on which they prey, as PCBs have been found in a variety of fish from many different waters.

PCBs have also been found in freshwater fish and terrestrial birds, although there is less published data on them than for marine organisms.

What is the Hazard?

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends levels of hazardous materials which should not be exceeded in occupational situations. The ACGIH recommendation for PCB containing 42 percent chlorine is the same as for DDT, namely, a maximum or "threshold limit value" of one milligram per cubic meter of air. (A "threshold" is said to be an amount below which no effect is noted.) But some PCBs are more heavily chlorinated, and for those with 54 percent chlorine, the ACGIH threshold limit value is half as much (0.5 milligram per cubic meter of air). Among the Aroclors listed for sale by Monsanto are chlorinated biphenyls that are up to 68 percent chlorine and mixtures of chlorinated biphenyls and chlorinated triphenyls that are up to 65 percent chlorine.

DDT reaches the environment by intent, PCB by accident.

The most extensive research on PCBs in wildlife in this country has been undertaken along the California coast, but PCBs have also been found in terrestrial and freshwater organisms.

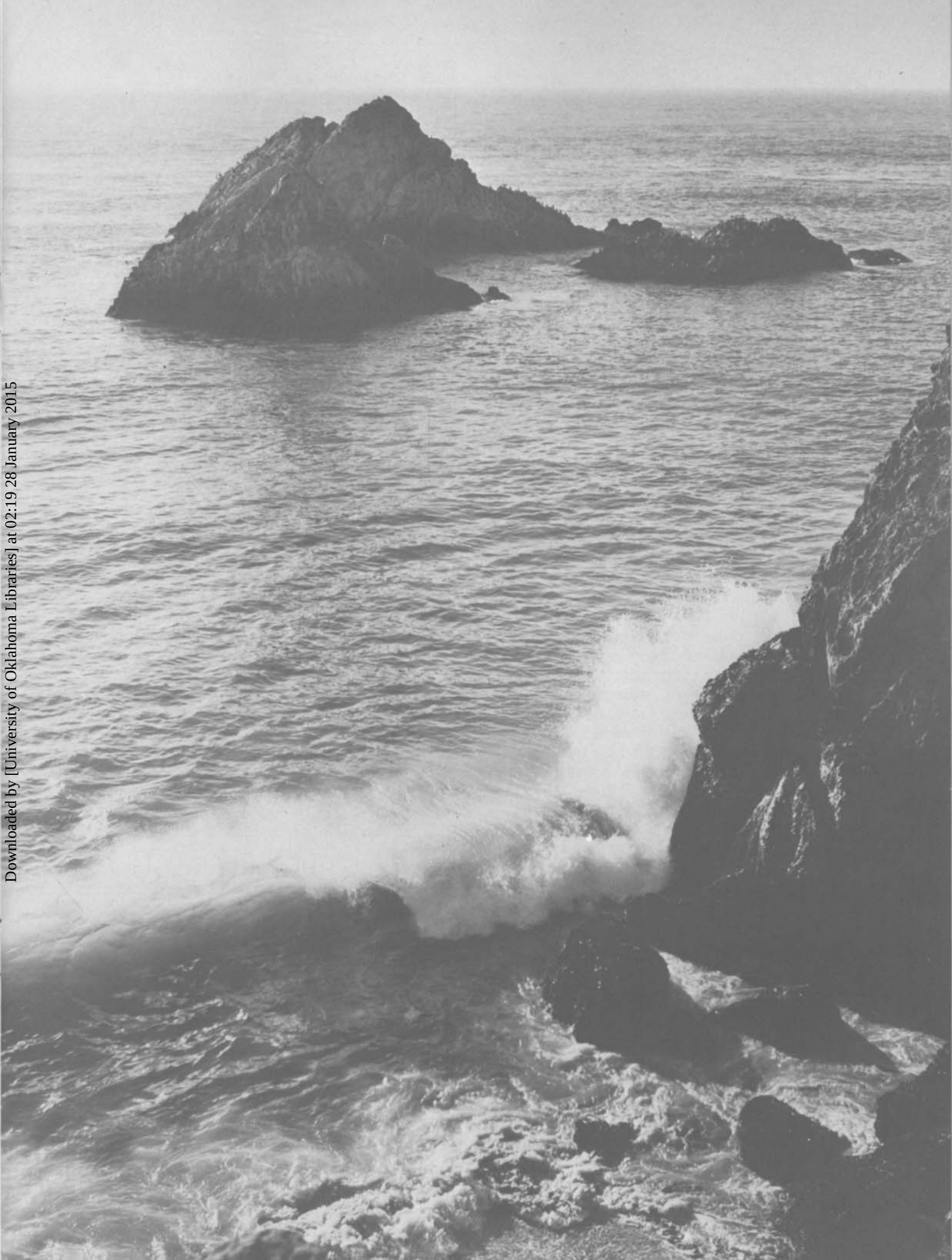
The more heavily chlorinated PCBs have been reported in wildlife both in the U.S. and in Europe, and have been found to be highly persistent in the bodies of fish and birds, while the more lightly chlorinated PCBs are somewhat less persistent, and are metabolized or excreted more rapidly. This was confirmed by a laboratory experiment by Koeman in which Japanese quails were fed a mixture of PCBs. After the birds died, it was found that some of the PCBs, particularly the more lightly chlorinated ones, had been metabolized. However, this is not necessarily reassuring. Little is known about the metabolites — the breakdown products — of PCB; one of the metabolites of DDT (DDE) affects the reproductive systems of birds.

PCBs are described in *Dangerous Properties of Industrial Materials* as affecting human skin and liver at high concentrations, although how high is not stated. The toxicology is described as follows:

> The lesion produced in the liver is an acute yellow atrophy. This hepatotoxic action of the chlorinated diphenyls [same as biphenyls] appears to be increased if there is exposure to carbon tetrachloride at the same time. The higher the chlorine content of the diphenyl compound, the more toxic it is likely to be. Oxides of chlorinated diphenyls are more toxic than the unoxidized materials.
>
> The skin lesion is known as chloracne, and consists of small pimples and dark pigmentation of the exposed areas, initially. Later comedones [blackheads] and pustules develop. In persons who have suffered systemic intoxication the usual signs and symptoms are nausea, vomiting, loss of weight, jaundice, edema and abdominal pain. Where the liver damage has been severe, the patient may pass into a coma and die.

Cases of occupational chloracne and of systemic damage were reported in the early years of PCB use. Experiments with laboratory animals also revealed the high toxicity of PCBs injected, fed or applied to the skin.

There is no evidence to indicate that PCBs in the environment are likely to reach levels which would cause severe injury or death from short-term exposure. The possible PCB hazard, like so many environmental hazards, is one of long-term, low-level



exposure and perhaps of effects from its combination with other poisons. There is also the more indirect, but no less real danger of destroying other forms of life — part of the vast interconnected web of species of which man is but one part and on which he depends.

The accumulating evidence that no part of the world is now free of pesticide residues, the products of atomic explosions, or of a variety of industrial pollutants, has induced subtle but profound changes in our concept of our position in the global ecosystem and in our individual conceptions of remoteness and isolation. There has never been any question that local ecosystems could be irreversibly changed by the introduction of synthetic chemicals, whether these introductions be purposeful or incidental. Since the sea, however, is the dominant feature of the worldwide ecosystem, interpretations of environmental contamination in terms of local ecosystems, whether terrestrial or aquatic, may be misleading. The accumulation in marine organisms of significant amounts of several pollutants — those such as PCBs which are insoluble in water, but soluble in fat — not only elicits an uncertainty about the long-term utilization of the sea as a source of human food, but has suddenly raised the question of the ultimate survival of a number of species of sea birds. These species comprise a very large fraction of the world's wildlife, and doubts about their future would have been considered preposterous and untenable only three or four years ago. Massive reproductive failures have been noted in 1969 in the brown pelican in Southern California. The jack mackerel fishery out of Los Angeles has just been closed because of the high levels of DDT in the fish.

In terms of the exposure of many forms of life and of people of all ages and states of health to PCBs, is there really a "threshold limit value"? Is there really an amount of polychlorinated biphenyl which is safe to breathe or to ingest? No threshold has been found for the effect of DDE on eggshell thickness, one of the problems which appears in the reproductive systems of birds that have ingested the pesticide. *Very* small amounts of DDE were found to cause some thinning of the shells.

The close similarity of DDT and PCB suggested the possibility that PCB might have similar physiological effects. Accordingly, David Peakall of the Langmuir Laboratory at Cornell University, investigated the effect of PCB on pigeons, and found that, like DDT, it induced (stimulated the production of) enzymes in the liver, enzymes which broke down estradiol, a sex hormone.

The entire reproductive cycle in birds, from the development of the male and female reproductive organs to the laying of the egg and the birth of the chick, is mediated by various sex hormones. When the work of a hormone has been done, it is broken down by enzymes in the liver. However, if the enzyme activity is artificially increased by the introduction into the body of a chlorinated hydrocarbon, it appears that the hormone will be broken down at a much faster rate. Among the effects of chlorinated hydrocarbon pesticides that have been found in birds are delayed laying of eggs, thin egg shells (sometimes so thin as to break) and chicks that die at hatching.

In Peakall's experiment, four groups of four birds each were used. The first group was given no chlorinated hydrocarbon. The second was injected with DDE (the persistent breakdown product of DDT); 40 milligrams of DDE per kilogram of body weight were injected. The third group was injected with 40 milligrams of DDT per kilogram of body weight, and the fourth with 20 milligrams of PCB per kilogram of body weight. The PCB used was Aroclor 1262, which is approximately 62 percent chlorine. One week later, the birds were killed, and the portion of the liver containing enzymes was removed. To each liver was added a tiny amount of the sex hormone, estradiol. The breakdown of the estradiol was increased two-and-a-half times by DDE, almost three-and-a-half times by DDT and five-and-a-half times by PCB, in spite of the fact that only half as much PCB was used.

J. C. Street and his co-workers at Utah State University investigated the effect of a series of ten PCBs ranging from 21 to 68 percent chlorine on female rats. All of them stimulated enzyme induction; the amount of stimulation increased regularly with the percentage of chlorine in the PCB. PCBs containing more than 50 percent chlorine were as potent in enzyme induction as DDT. This is particularly interesting in view of the Monsanto statement that "no adverse effects" have been found in rats or other laboratory species fed up to 100 parts per million. (Street fed rats from 50 to 100 parts per million.) Induction of these enzymes would be one of the expected effects of the polychlorinated biphenyls in people. Normally the lifetime of the induced enzymes is short. The foreign, water-insoluble compounds

(continued on page 23)

REMINDER

This issue is the January/February issue, one of two double issues published during the year (the other will be the July/August one). The next magazine you receive will be the March issue.

Little is known as yet about what happens between the manufacture of PCBs and their appearance in the bodies of birds, fish and people. One possible source of the PCBs in the environment is manufactured products incorporating PCBs which are eventually thrown away and may be burned, as in the apartment house incinerator shown at right, releasing the compounds or their more toxic oxides into the atmosphere.

Chicago-American

(continued from page 22)

that act as inducers are usually converted to water-soluble derivatives that can be excreted by the kidney. Enzyme activity falls as the inducers are metabolized in this way. The polychlorinated biphenyls, however, particularly those with greater amounts of chlorine, are relatively resistant to biological breakdown. They might therefore persist as inducers without being broken down themselves. As the enzymes are continually induced, hormones and perhaps other classes of molecules as well might therefore be metabolized at rates faster than normal over the whole life span of the organism. The long-term significance of this phenomenon is as yet unknown. Investigation of various possible effects of the enzyme activity might be undertaken in workers with a long history of exposure to PCBs.

Very little data is available about PCBs in people. Both Swedish and British scientists have reported finding them in a few samples of human fat. In North America the profile of the PCB compounds on gas chromatograms of human milk samples was found by Dr. James Enderson and Fred Beland of the Colorado College in Colorado Springs. Although the air of Colorado Springs is much cleaner than the air of our larger cities, it was not evident whether the people of Colorado Springs were obtaining the PCB in their food or were inhaling it. The senior author then measured the PCB in a series of mothers' milk samples from Berkeley and from Los Angeles. Every sample tested contained both PCB and DDT compounds. As is well known, the DDT content in mothers' milk is above the maximum concentrations permitted in cow's milk. The Berkeley mothers' milk

PCB is widely distributed among marine birds which are at the top of a complex mesh of food chains in the sea, including the Leach's petrel shown here. The accumulation of significant amounts of several pollutants, including PCBs, in marine wildlife, not only elicits an uncertainty about the long-term utilization of the sea as a source of human food, but has suddenly raised the question of the ultimate survival of a number of species of sea birds.

Allen H. Morgan — Mass. Audubon Society

contained about four times the legal tolerance limit. The Los Angeles mothers' milk had somewhat less DDT, but because of the wide variation within each series, the differences were not significant. The PCB concentrations in both series averaged about 0.06 parts per million of the whole milk.

We can no longer assume that the Berkeley air is cleaner than the air of Los Angeles, and we still do not know therefore how much of the PCB in people derives from food and how much is absorbed by the lungs from the air. We did find, however, very small amounts of PCB in a sample of cow's milk, and it is present in higher concentrations in fish which are eaten by people.

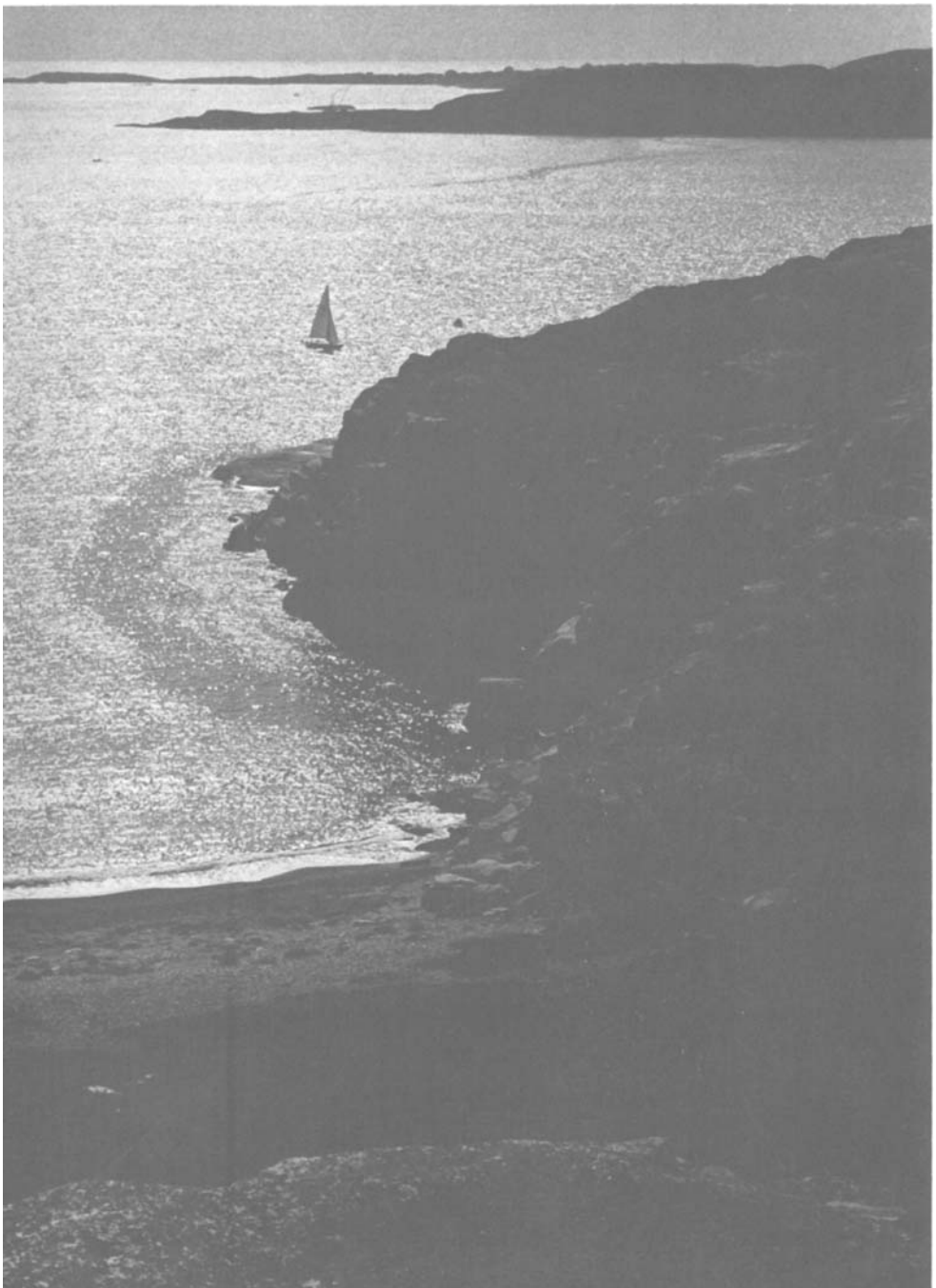
Establishment of tolerance limits of PCB in food is clearly essential. Under present law a manufacturer of pesticides must petition for a tolerance limit for each pesticide on each food crop treated with the particular pesticide. Food shipments contaminated with pesticides are subject to condemnation if they exceed the tolerance or if no tolerance limit has been set for that particular food. The jack mackerel of the Pacific coast and the coho salmon of Lake Michigan, seized and condemned by the Food and Drug Administration because they contained high levels of DDT, contained PCB in addition to the DDT compounds.

PCBs are available in containers ranging from 50-pound cans to 600-pound steel drums, and by the tank carload.

A thorough investigation of the physiological effects of the agricultural and industrial chlorinated hydrocarbons, including their effects on the reproductive systems of both birds and mammals, is urgent. We would do well to act on the basis of data from laboratory animals and wildlife rather than waiting for definitive knowledge from studies of people. Effects on people might not show up for many years and would be extremely difficult, if not impossible, to relate to one specific cause. An effect might derive from the interactions of two or several pollutants. The white-tailed eagles studied by Jensen in Sweden contained PCB, DDT and mercury compounds.

The PCB in birds, fish, and people might derive from only a few of the PCB uses which release a comparatively large amount of these compounds into the environment. Release of hydraulic oils containing PCB into waterways might be one of these. It is also possible that each manufactured product containing PCB, which like all manufactured products eventually becomes a waste product, will eventually release PCB into the environment, just as any DDT use will eventually increase the environmental burden of DDT. We very much need therefore to establish the sources of the environmental residues of PCB and to trace the paths by which they move through our environment. If PCB should prove to be

Monsanto manufactures Aroclor (trade name for PCBs) at this Sauget, Illinois plant and at a plant in Anniston, Alabama. No data is available on the loss to the environment of PCBs in the course of the manufacturing process, nor on the losses at other plants where products are manufactured which contain PCBs.



Swedish scientists have found PCBs in mussels, plaice, cod, and dogfish from remote parts of the west coast, like that shown at left.

an uncontrollable chemical like DDT, it will not be possible to speak of "controlled" uses.

PCB therefore appears to be another waste product of our technology that is not recycled to primary materials. Although there are unquestionable economic advantages derived from their use, the diminishing capacity of our global environment to absorb our own wastes should prompt us to consider whether — and how — we can develop a technology that can use its waste materials again and again and that does not permit any persistent wastes with biological activity to accumulate. □

Monsanto Statement on PCB

When this article was in preparation, the Monsanto Company was invited to provide a statement of its position on PCBs. A series of questions was also addressed to the company. The answers to some of these questions have been incorporated into the text of the article. Others follow the Monsanto statement.

Late in February, 1969, a West Coast newspaper carried a major feature about "a menacing new pollutant" found in the San Francisco Bay area. The article was based on marine life research carried out by Dr. Robert Risebrough of the University of California. The article stated that residues of pesticides (DDT and DDE) and polychlorinated biphenyl (PCB) were threatening the welfare of certain birds and posed a long-term threat to humans.

Monsanto manufactures polychlorinated biphenyl and markets it under our Aroclor trade name. (There are other manufacturers in Europe and Japan.) We, therefore, would like to present some additional facts.

The work done by Dr. Risebrough dates back to earlier research by other scientists who, while analyzing pesticide residues in wildlife, soil and water, encountered unknown or "interfering" substances in the parts-per-million range.

Several years ago, two Swedish scientists at Stockholm University's Institution of Analytical Chemistry, Professor Gunnar Widmark and Soren Jensen, reported they had identified these other substances. They said some of the materials were polychlorinated biphenyl or PCB. Since PCBs are not "broadcast" or spread around the land as are pesticides, the scientists theorized that the source must be the industrial wastes of PCB users.

In addition to the work of Dr. Risebrough and the Swedish scientists, there have been other studies which indicate the presence of PCBs in the environment. Monsanto is concerned over the situation and is cooperating fully with these studies.

The common uses of commercial PCB would not normally lead to its release into the natural environment.

A principal market for PCB is in electrical applications where they are used as insulating fluids for transformers and capacitors. In this use, the chemical is completely sealed in metal containers. Another market is for heat-transfer applications where the PCB fluid functions in a closed system.

PCBs are also used in several applications where the chemical is incorporated into a polymer as an integral part of the solid material. Such polymers are used in highly specialized applications as an adhesive, elastomer or surface coating.

Polychlorinated biphenyls are not sprayed or dusted on crops, woodlands or any other areas, as are pesticides. To our knowledge, they are not used in tires, house paints, household products, or major vinyl plastics, as has been charged. Therefore, conclusions as to the source of PCB reportedly found in the environment are difficult to make.

It has also been implied that polychlorinated biphenyls are "highly toxic" chemicals. This is not true. Just like other industrial chemicals and home products now in widespread use, PCBs are not hazardous when properly handled and used. During more than 40 years of U.S. production and use, cases of any toxic effect have been extremely rare — and then only where the simple precautions recommended for use were not followed.

Monsanto has research programs under way to identify the compounds, reported to be PCB, and locate their source. The programs involve precise analysis of environmental samples of water and soil. Also under way are studies to determine the biological effects of deliberate dosage of PCBs on fish and mammalian animals. Special emphasis is being paid to endocrinological effects, mineral metabolism and reproduction physiology.

Some preliminary biodegradability studies are under way. Further studies to clearly demonstrate this phenomenon are contemplated.

Very early results of chronic toxicity studies confirm that PCBs are not highly toxic. In 90-day studies on rats and other normal laboratory species, there have been no adverse effects when feedings of up to 100 parts per million were administered.

Monsanto has always cooperated on a regular basis with federal, state and university laboratories in their analysis of chlorinated hydrocarbon residues. We will

NOTES

p. 16. *". . . but a Monsanto bulletin. . . ."*
Technical Bulletin O/PL-306, Organic Chemicals Division, Monsanto, St. Louis, Mo., 1968. We are informed by a Monsanto spokesman that supplies of this bulletin "have been exhausted for several months, and it is in the process of being revised . . . the old bulletin . . . covers only the plasticizer applications, many of which are only suggested applications. To our knowledge, Aroclor plasticizers are not used in all the applications suggested in the bulletin. Primary markets are chlorinated rubber, styrene-butadiene copolymers and polysulfide sealants. Aside from plasticizers, the principal market for polychlorinated biphenyls is in electrical applications where the insulating fluids used in transformers and capacitators are completely sealed. In another major market, heat transfer applications, the fluid is used in closed systems."

". . . report by Soren Jensen. . . ."
"Report of a New Chemical Hazard," **New Scientist** 32:612, 1966.

p. 17. *". . . Gunnar Widmark . . . human fat."*
Widmark, G., "Possible Interference by Chlorinated Biphenyls" in "Pesticide Residues" Report of the IUPAC Commission on the Development, Improvement, and Standardization of the Methods of Pesticide Residue Analysis, **Journal of the Association of Official Analytical Chemists** 50:1069, No. 5, 1967.

"Scientists in Britain. . . ."
Holmes, D.C., J. H. Simmons and J. O'G Tatton, "Chlorinated Hydrocarbons in British Wildlife," **Nature** 216:227, 1967. Holden, A. V., and K. Marsden, **Nature** 216:1274, 1967.

". . . and the Netherlands. . . ."
Koeman, J. H., M. C. Ten Noever De Brauw and R. H. De Vos, "Chlorinated Biphenyls in Fish, Mussels and Birds from the River Rhine and the Netherlands Coastal Area," **Nature** 221: 1126, March 22, 1969.

"Jensen and his colleagues . . . Swedish Wildlife."
Jensen, S. et al., "DDT in Marine Animals from Swedish Waters," **Nature** 224:247, 1969.

". . . unknown compounds were polychlorinated biphenyls."
Note: Laboratory procedures in this and subsequent analyses for PCBs are described in the papers listed above and in the author's scientific papers. See especially, Risebrough, R. W., P. Reiche, D. B. Peakall, S. G. Herman and M. N. Kirven, "Polychorinated Biphenyls in the Global Ecosystem," **Nature** 220:1098, 1968. Risebrough, R. W., P. Reiche and H. S. Olcott, "Current Progress in the Determination of the Polychlorinated Biphenyls," **Bulletin of Environmental Contamination and Toxicology** 4:192, 1969.

p. 18. *". . . 1,980* PCB *. . . 17,000 parts per million. . . ."*
Risebrough, et al., "Polychlorinated Biphenyls in the Global Ecosystem," **op. cit.** Jensen, S., **op. cit.**

p. 19. *". . . may be released as a vapor in the form of highly toxic fumes."*
Sax, N. Irving, **Dangerous Properties of Industrial Materials,** 2nd Ed., Reinhold Publishing Co., New York, 1968, p. 34.

p. 20. *". . . a complex mesh of food chains in the sea. . . ."*
Risebrough, R. W. "Chlorinated Hydrocarbons in Marine Ecosystems" in **Chemical Fallout,** Morton W. Miller and George C. Berg, editors, Charles C. Thomas, 1969.

". . . 'threshold limit value' of one milligram. . . ."
Sax, N. Irving, **op. cit.** p. 34.

". . . more lightly chlorinated PCBS. . . ."
Jensen, S. et al., **op. cit.**

". . . laboratory experiment by Koeman. . . ."
Koeman et al., **op. cit.**

". . . laboratory animals . . . high toxicity. . . ."
Miller, J. W. "Pathologic Changes in Animals Exposed to a Commercial Chlorinated Diphenyl," **U.S. Public Health Record** 59:1085, 1944. McLaughlin, Joseph, Jr., Jean-Pierre Marliac, M. Jaqueline Verrett, Mary K. Mutchler and O. Garth Fitzhugh, "The Injection of Chemicals into the Yolk Sac of Fertile Eggs prior to Incubation as a Toxicity Test," **Toxicology and Applied Pharmacology** 5:760, 1963.

p. 22. *". . . jack mackerel fishery. . . ."*
"DDT Report Halts Fishing," **The New York Times,** Dec. 7, 1969.

"The breakdown of the estradiol . . . ."
Results were in average amounts of polar metabolites formed in millimicromoles for each group of four birds: Control — 29.3 plus or minus 6.5; DDE — 76.2 plus or minus 13.1; DDT — 93.1 plus or minus 11.2; PCB — 160.0 plus or minus 10.5.

"J. C. Street and his co-workers. . . ."
Street, J. C., F. M. Urry, D. J. Wagstaff and A. D. Blau, "Comparative Effects of Polychlorinated Biphenyls and Organochlorine Pesticides in Induction of Hepatic Microsomal Enzymes," presented at the 158th American Chemical Society national meeting, New York, Sept. 8-12, 1969.

continue to do so. Additionally, Monsanto will continue to exercise the highest degree of control in its manufacturing, shipping and storing of PCB — as we do with all products. In the functional fluids market, we have carried out a program for several years for the reclamation of used PCBs to reuse these valuable materials.

The source of the marine life residue identified as PCB is not yet known. It will take extensive research on a worldwide basis, to confirm or deny these initial scientific conclusions.

Questions from ENVIRONMENT and answers from MONSANTO.

Environment: At which Monsanto plants is Aroclor manufactured?

Monsanto: In the United States, Monsanto presently manufactures its Aroclor products at plants located in Sauget, Illinois, and Anniston, Alabama.

Environment: Have you monitored emissions at those plants for the presence of PCB? If so, what were the results?

Monsanto: Extensive efforts are in practice at these plants to prevent PCB losses to the environment. These practices have been in use for many years and controls are continually being improved.

Environment: Does Monstanto itself incorporate PCB into some of its other products? If so, at which plants? Have emissions from these plants been monitored for the presence of PCB? With what results?

Monsanto: Controlling practices are also in effect to prevent loss in those manufacturing operations where Aroclor is incorporated into other Monsanto products.

Environment: Could you tell us what control measures you use to keep the PCB concentrations below the Threshold Limit Value in the plant atmosphere?

Monsanto: (No answer)

Environment: We would be pleased to receive any additional information, such as scientific reports, advertising copy, or any other material you may have on PCB. We would appreciate very much seeing copies of the original work you have done on the toxicity of Aroclors.

Monsanto: Our research department summarized some of their work and . . . I am making it an enclosure.

Editor's note: The enclosure dealt only with residue analysis, not with toxicity.