PCBs: Their Environmental Significance and Distribution in Rhode Island

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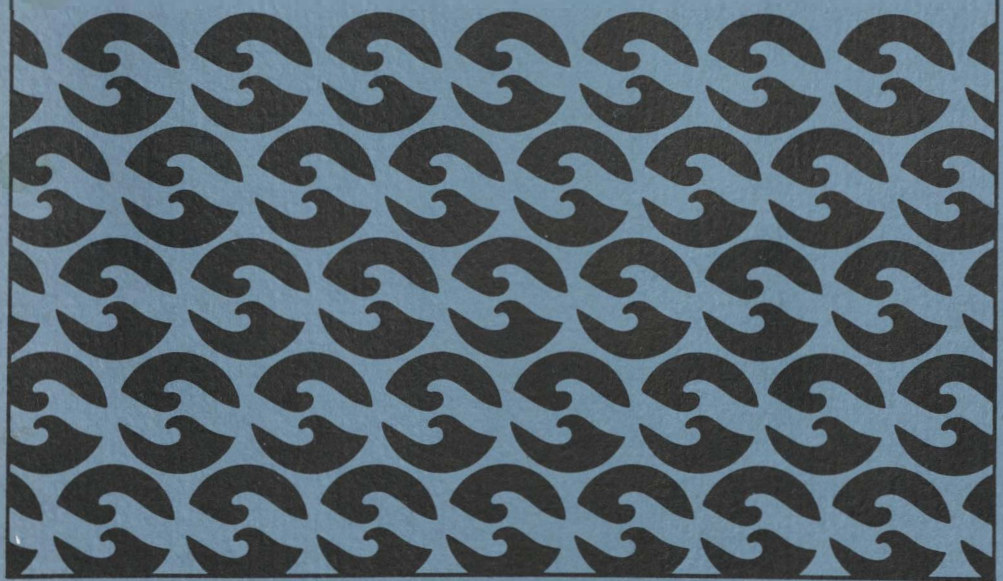
NOAA



University of Rhode Island Marine Technical Report 68

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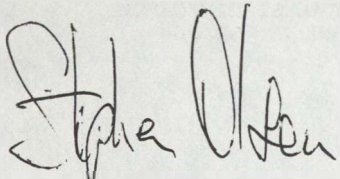
PREFACE

A part of the process of developing the Rhode Island Coastal Resources Management Program has been the compilation of detailed information on a number of resources and management problems. PCBs are recognized as a particularly worrying pollutant; this review summarizes present knowledge about them and their occurrence in Rhode Island coastal ecosystems. This is one in a series of technical reports produced by the Center.



Stephen Olsen, Coordinator
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TERMINOLOGY

The units ppm, ppb, and ppt refer to concentrations and stand for parts per million, per billion, and per trillion, respectively. For PCBs in water, 1 ppb represents 1 part PCB in 1 billion parts of water and thus is equivalent to 1 microgram of PCB in 1000 grams (1 liter) of water. 1 ppb = 1 ug/l. In solid samples (e.g., sediments or tissue) these units (ppm, ppb, and ppt) are always expressed on a weight-to-weight basis.

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SUMMARY

PCBs (polychlorinated biphenyls) were first manufactured for commercial use in 1930. Chemical properties of these synthetic compounds have made them extremely useful in a wide variety of products, such as electrical equipment, paints, and inks. United States production of PCBs reached a peak of 38.6 kilotons/year in 1970 (Goldberg, 1976). In the late 1960s, PCBs were identified in wildlife in Sweden and Great Britain (Holmes et al., 1967). Concern over the possible environmental damage being caused by these compounds arose when declining bird populations were found to have high PCB levels. Research performed during the past decade has shown that PCBs cause both acute and sublethal toxic effects in a wide variety of terrestrial and aquatic organisms. The low reactivity of these compounds enhances their commercial usefulness but also retards their degradation. Thus, PCBs retain their toxic properties for considerable lengths of time as they are transported through the environment. Contamination by PCBs is not restricted to areas of known discharges as these compounds are now globally distributed. Reductions in the amounts of PCBs produced, restrictions on the kinds of products in which they are used, and discharge limitations are currently reducing new inputs of PCBs into the environment. However, a tremendous amount of these compounds have already been produced and will continue to pose a hazard. PCBs released into the environment resist degradation for decades; they have been identified in sediments deposited as far back as the 1940s (Hom et al., 1974).

This report is divided into two sections. The first section provides summary information on PCB chemistry, sources, transport mechanisms, and toxicity, with focus on the marine environment. In the second section, the existing data on PCBs in Rhode Island are presented and assessed. From this review and assessment the following conclusions can be made:

1. PCBs, although present in the Rhode Island environment, are not a major pollution problem.

2. Data on PCBs in Rhode Island ecosystems are scanty. Additional information would provide a clearer picture of PCB distribution but is not considered to be of high priority, since the available data suggest that present levels are low.

3. Although no major industrial discharges of PCBs are present in Rhode Island, low levels of contamination are expected to continue from disposal of sewage effluent and sludge and solid waste. Landfill sites pose the greatest potential hazard, due to the possible release of PCBs from sewage sludge and other deposited materials.

BACKGROUND INFORMATION ON PCBs

Chemistry

Polychlorinated biphenyls are man-made compounds with no natural analogs. They belong to a group of chemical compounds called halogenated hydrocarbons, which also includes the pesticide DDT and its derivatives. This group is characterized by stability in the environment and is known to have lethal and sublethal effects on organisms. The chemical and physical properties of PCBs which have made them useful in commercial products include low vapor pressures at ambient temperatures, resistance to combustion and to acid-base hydrolysis, low water solubility, high dielectric constant, and high specific electrical resistivity.

PCBs, specifically, are composed of biphenyls in which a chlorine atom has replaced a hydrogen atom at one or more of ten positions. There are 210 possible PCB compounds. Due to the nature of the chemical reaction during production, PCBs are synthesized as mixtures of many compounds, only a few of which are produced in high yields. Monsanto, the only United States manufacturer of PCBs, produced them as a series of mixtures under the trade name Aroclor 1200. The last two digits indicate the weight percent chlorine in the mixture.

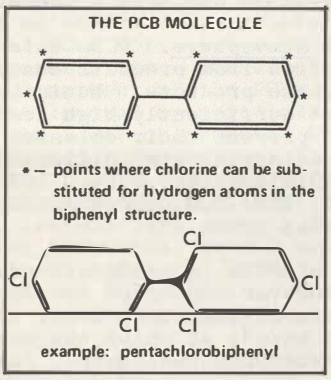

Figure 1. Structure of the PCB Molecule

From the University of Wisconsin Sea Grant College Program, 1976

PCBs measured in water, sediment, or biological samples are reported as the mixture which most resembles the market product, e.g., reported as "Aroclor 1254." This identification is more qualitative than quantitative, but gives an estimate of the degree of chlorination and the proportions of the different compounds in the mixture. The reported mixture may differ from the original PCB contaminant, since chemical and biological fractionation can alter the composition of the mixture.

Sources, Transport, and Fate of PCBs

PCBs may enter the environment in a number of ways: burning of PCB products, leakage from electrical equipment, direct discharge into waterways, and disposal at landfills and dumps. Nisbet and Sarofim (1972) estimated that in 1970, 72 percent of the PCBs entering the environment were disposed of in landfills and dumps, 20 percent were directly introduced to aquatic and marine systems, and 8 percent were released into the atmosphere. Once released, the concentration and composition of PCBs in any particular ecosystem component is determined by biological, chemical, and physical parameters. Characteristics important in governing the distribution of PCBs in the environment include their low solubility in water, high solubility in lipids and oils, a high tendency to bind to soils and sediments, and their resistance to degradation by heat or biological processes.

Release into the Atmosphere. PCBs enter the atmosphere through vaporization from products containing PCBs and the burning of these products. Municipal incinerators do not operate at sufficiently high temperatures to destroy PCBs and prevent their emission into the atmosphere. Rural continental air (Bidleman et al., 1976) and marine air (Bidleman and Olney, 1974; Harvey and Steinhauer, 1974) have PCB concentrations an order of magnitude less than urban air.

Absolute levels of PCBs in urban air are higher than those of DDT. However, observed levels of both substances are orders of magnitude lower than the concentration (100,000 ng/m^3) at which the more toxic DDT is reported to be hazardous (Matsumura, 1975).

Atmospheric transport has been suggested as a mechanism to explain the presence of PCBs in areas remote from known discharges (National Academy of Sciences, 1971). Airborne inputs may represent a low but significant chronic source of PCBs to marine ecosystems. Proposed mechanisms for the removal of PCBs from the atmosphere include scavenging from dry fallout, rainfall, and air-sea exchange (Bidleman et al., 1976).

Direct Discharge into Surface Waters. Direct discharge of industrial and domestic wastewater is probably the major source of PCBs in fresh and coastal waters. Once in the water, PCBs, like other chlorinated hydrocarbons, probably associate with humic and suspended matter (Huang and Liao, 1970; Choi and Chen, 1976; Poirrier et al., 1972; Crump-Wiesner et al., 1974; and Pierce et al., 1974) and are deposited in the sediments very near a point source. For example, Nadeau and Davis (1976) reported that PCB concentrations in Hudson River water decreased from 2800 ppb (ug/l) near a sewage outfall to 22 ppb one quarter of a mile downstream. At this same outfall the sediment contained 7600 ppm PCBs, while one mile downstream the sediments contained only 6.6 ppm.

As PCB concentrations in surface waters decrease as a result of Environmental Protection Agency discharge limitations, contaminated sediments may, due to equilibrium considerations, be expected to slowly release PCBs. Thus, sediments themselves may act as a continuing source of PCBs to the overlying waters for many years. Such releases could also create a hazard at the disposal site of PCB-contaminated dredge spoils.

Land Disposal. It is estimated that more than 60 percent of the PCBs produced before 1970 are now deposited in landfills and dumps (Nisbet and Sarofim, 1972), suggesting that 300,000 tons of PCBs have accumulated in these areas. Their release may be slow, since the breakdown of containers such as capacitors may take many years. The high affinity of PCBs for soils retards their migration from land disposal sites. Tucker et al. (1975) found that only 0.05 percent of the PCBs on highly contaminated soils were leached by percolating water. The leached PCBs were the lower chlorinated biphenyls, which are more easily degraded. However, in field studies conducted by the EPA in 1976, PCBs were detected in surface leachate and groundwater samples at levels up to 85 ppb and 46 ppb, respectively, at six New England landfill sites receiving industrial or PCB wastes (Environmental Protection Agency, 1976a). The rates, distance, and amounts of PCB migration from land disposal sites have not been thoroughly examined.

Biological Pathways. The biological pathways of PCBs in the marine environment are not clearly understood at this time. It has been shown that PCBs accumulate in some aquatic organisms to levels exceeding ambient water concentrations. Among the highest concentration factors reported are those of 10^7 found in fish in field studies in Lake Ontario (Environmental Protection Agency, 1977).

Interpretations of data concerning bioaccumulation vary. Passive partitioning of PCBs between the lipids of an organism and the water may cause elevated PCB concentrations in some instances. Sodergren (1968) and Urey et al. (1976) have shown that dead plant cells accumulate PCBs just as efficiently as live cells, supporting the theory of a chemical partitioning process in lower trophic levels. However, there is some evidence for increased accumulation at higher trophic levels, suggesting that dietary exposure to PCBs may also be important. When the increased fat content of organisms at high trophic levels is taken into account, PCB levels on a lipid weight basis may remain constant, as suggested in field studies in the North Sea (Ten Berge and Hillebrand, 1974) and in waters off Finland (Linko et al., 1974). Harvey et al. (1974) also found no evidence of PCB magnification from one trophic level to another.

Because sediments are likely to be more contaminated with PCBs than are the overlying waters, benthic organisms may be an important component of biological pathways of PCBs in the marine environment. In laboratory studies (Duke, 1974), oysters and blue crabs have been shown to accumulate PCBs to concentrations 10^3 to 10^5 times greater than ambient water concentrations. It is not known to what extent benthic deposit feeders may accumulate PCBs from contaminated sediments ingested during feeding. Snails sampled in the vicinity of a PCB discharge in the Hudson River contained higher concentrations of PCBs than either the water or the sediments. The mechanism of accumulation was not determined (Nadeau and Davis, 1976). The importance of benthic invertebrates as a food source for many fish species increases the potential hazard associated with contamination of benthic communities.

Marine birds (Risebrough et al., 1968) and marine mammals (Taruski et al., 1975) are able to concentrate PCBs in their fats to a much greater extent than other marine organisms, and thus may be especially susceptible to effects of PCB pollution.

Present Trends of PCB Releases in the Nation

The rates and patterns of input of PCBs into the marine environment are changing. In 1971, usage of PCBs in the United States was restricted to closed systems which would contain the PCBs during the lifetime of the product. In February 1977, effluent standards were set prohibiting discharges of PCBs by manufacturers of PCBs, transformers,

or capacitors. Under the Toxic Substances Control Act of 1976 disposal of PCB products is restricted to high-temperature incineration or placement in chemical waste landfills. With suitable alternative, non-PCB electrical fluids now available, Monsanto ceased manufacturing PCBs in the fall of 1977. All PCB processing and distribution will be prohibited after June 1, 1979. As a result of these actions, PCB releases into the environment are significantly reduced from pre-1971 levels. However, releases have not been and cannot be eliminated. There will continue to be a slow release from the many tons of PCBs already deposited in landfills. Sewage flows into municipal treatment plants continue to be contaminated with PCBs. These PCBs are not destroyed in the treatment process, and thus are released with the treated effluent or are contained in the sewage sludge. Therefore, the fate and impact of PCBs in marine ecosystems will continue to be of significant concern.

Toxicity

Considerable effort is now being made to determine the effects on organisms of exposure to potentially toxic substances. There are two primary purposes for such research: to allow the prediction of biological impacts that may occur as a result of environmental contamination and to define safe levels of exposure, that is, exposure causing no or negligible impacts. However, the complexity of natural ecosystems prevents exact predictions and definitions in many instances. Acute toxicity studies, which monitor the mortality of organisms exposed to relatively high levels of a substance, provide information on the relative toxicity of various compounds to the organisms tested. The responses of organisms chronically exposed to low levels of contaminants are more accurately reflected in experiments designed to observe sublethal adverse impacts, such as changes in physiological processes, growth rates, reproductive success, or behavior patterns. However, the controlled conditions under which such experiments are performed cannot duplicate the natural variability displayed by the chemical, physical, and biological parameters of an ecosystem. Thus, the information available on the effects of most toxins, including PCBs, once they are released into the environment is sketchy in terms of assessing what organisms will be affected and to what degree.

Humans and Other Mammals. PCBs have been shown to be harmful to humans and other mammals. PCBs have been associated with chloracne, an occupational disease characterized by skin lesions (Schwartz and Peck, 1943). In 1968, a skin disease called Yusho broke out in Japan. Symptoms included excessive eye discharge, pigmentation of the

skin, acne-form eruptions, palsy, fatigue, and vomiting. Liver damage was reported in some patients. This disease, which resulted in four deaths, was attributed to contamination of rice oil by PCBs (Kuratsume et al., 1972). At this time it is not known whether the disease symptoms are caused by PCBs themselves or by chlorinated dibenzofurans, a contaminant in the manufacture of PCBs (Bauer et al., 1961; Nagayama et al., 1976).

The outbreak of Yusho clearly demonstrates that PCBs pose a hazard to human health. However, determining the minimum levels of exposure that may be harmful is a difficult task, dependent largely on data from experiments with animals. Laboratory studies on mammals indicate that PCBs in the diet can result in death or sublethal effects. The dietary concentrations causing these impacts vary with the species. Rats, mice, and dogs survived for one to two years on diets including 100 to 300 ppm PCB, while dietary levels as low as 3 ppm were fatal to rhesus monkeys after 245 days (Environmental Protection Agency, 1977).

In 1973, the Food and Drug Administration established a maximum limit for PCBs in fish and shellfish intended for human consumption of 5 ppm. They have since proposed to reduce this limit to 2 ppm.

Marine Organisms. Both acute and chronic exposures to PCBs have been shown to have adverse impacts on some marine organisms. The EPA (1976b) has summarized the results of research on the effects of PCBs. The toxicity and sublethal changes resulting from exposure to PCBs vary with the PCB mixture and the species tested. For example, in a survey of certain estuarine organisms from Escambia Bay, Florida, Aroclor 1254 was found to be particularly toxic to some fish, causing mortality in sheepshead minnow fry at 0.1 ppb (ug/l). However, no apparent effects were noted in pinfish at concentrations of 100 ppb. Oysters were not affected by concentrations of 1.0 ppb, although growth rates were reduced at 4.0 ppb and tissue alterations occurred at 5.0 ppb (Duke, 1974).

The responses of algae to PCBs also vary among different species. As a result, the species composition of phytoplankton populations can be altered by exposure to this pollutant (Hawes et al., 1976; Keil et al., 1971; Mosser et al., 1972). In situ bioassays of natural marine phytoplankton communities demonstrated that PCB concentrations greater than 1 to 2 ppb caused a reduction in carbon dioxide uptake, a measure of photosynthesis (Moore and Harris, 1972).

There are presently no standards for ambient concentrations of PCBs in water. The criterion proposed by EPA for marine waters is 1 ppt, based on results of toxicity studies, accumulation factors in marine organisms, and possible contamination of food species (Environmental Protection Agency, 1976b).

PRESENCE OF PCBs IN RHODE ISLAND

Air

All air samples analyzed for PCBs in Rhode Island (Table 1) show concentrations at least 1,000 times less than the minimum hazardous level for the more toxic DDT (Matsumura, 1975). The urban Providence sample is higher than the more rural, Kingston samples, but it is ten times less than a sample reported for Chicago.

Water

Table 2 presents data from PCB analyses of Rhode Island waters in 1972. In the freshwater systems, where most of the samples were taken, concentrations were below the detection limit of 50 ppt in all samples. The Pawtuxet River showed interference from other organic compounds, making PCB determination impossible. In two samples taken from Narragansett Bay's West Passage, PCB concentrations were below the detection limit in one subsurface sample and 150 ppt in the other. The Bay sample containing measurable PCBs was deliberately taken below a naturally formed surface slick found to be enriched in PCBs as well as other pollutants. Thus, this sample may not be representative of average water-quality conditions in the West Passage (Olney, personal communication).

Because of the high detection limit achievable at the time, all that can be concluded is that in 1972 one sample exceeded the 1976 proposed water-quality criterion by a factor of 150, while all others were less than 50 times the proposed criterion.

Restrictions in the use of PCBs since 1971 probably have reduced the water concentrations since the 1972 analyses were made. New large-volume collection systems make possible detection of PCBs down to 0.2 ppt. With these new techniques it would now be possible to survey Narragansett Bay to determine the source and extent of PCB pollution in this estuarine system more accurately.

Fish and Plants

With one exception, PCB concentrations in fish samples from Rhode Island's freshwaters range from less than 10 to 419 ppb (wet weight), as shown in Table 3. A bluegill from Print Works Pond contained 2580 ppb PCB; however, sediments from this pond did not contain exceptionally

Table 1. Atmospheric Concentrations of PCBs

Sample	Location	Volume of Air sampled (m^3)	PCB concentration (ng/m^3)	Ref.
A1	Bermuda	1070	0.6	1
A14	URI, Kingston, RI	392	4.0	1
A15	URI, Kingston, RI	1071	2.1	1
A16	URI, Kingston, RI	744	5.8	1
A17	Providence, RI	76	9.4	1
1	Chicago, Ill.		170.0	2
2	Chicago, Ill.		140.0	2
Threshold limit for DDT in breathed air,			100,000.0	3

References

1 Bidleman and Olney, 1974
2 EPA, 1975
3 Matsumura, 1975

Table 2. PCBs in Rhode Island Waters, 1970-1971

Location	PCB concentration (ppb)	Ref.
Slatersville Reservoir, North Smithfield	ND	1
Nichols Pond, Burrillville	ND	1
Keech Pond, Glocester	ND	1
Waterman Reservoir, Glocester	ND	1
directly below orchard	ND	1
Woonasquatucket Reservoir, Smithfield	ND	1
Olney Pond, Lincoln	ND	1
Scituate Reservoir, Scituate, at Bridge 251, Rte. 116	ND	1
stream from Barden Reservoir	ND	1
stream from Westonnaug Reservoir	ND	1
Stream from Flat River Reservoir, Coventry	ND	1
Pawtuxet River and tributaries, Cranston	Chromatograms of these samples contained many peaks that did not match PCB or pesticides. Samples at mouth of river were highest in these organics.	
at mouth		
at Elmwood Ave. Bridge		
Print Works Pond		
Alton Jones Pond, West Greenwich	ND	1
Belleville Pond, North Kingstown	ND	1
Annaquatucket River, North Kingstown, at Rte. 1	ND	1
Indian Lake, South Kingstown	ND	1
Cards Pond, South Kingstown	ND	1
Yawgoog Pond, Hopkinton	ND	1
Ell Pond, Hopkinton	ND	1
Moscow Brook, Hopkinton	ND	1
Locustville Pond, Hopkinton	ND	1
Yawgoo Pond, North Kingstown	ND	1
Thirty Acre Pond, South Kingstown	ND	1
Tuckers Pond, South Kingstown	ND	1
Wood River Pond, Richmond	ND	1
Brickyard Pond, Barrington	ND	1
One Hundred Acre Cove, Barrington	ND	1
Melville Pond, Portsmouth	ND	1
Easton Pond, Newport, east and west sides of dyke	ND	1
Jamestown Reservoir, Jamestown	ND	1
Narragansett Bay, near mouth of West Passage		
Sample 1 (subsurface)	ND	2
Sample 2 (subsurface)	0.15 + 0.04	2

References

1 Olney, 1972
2 Duce et al., 1972

ND none detected (less than 0.05 ppb)

Table 3. PCBs in Rhode Island Fish and Plants

Location	Specimen	PCB concentration (ppb)*	Aroclor type	Ref.
Freshwater				
Keech Pond, Glocester	perch	10	1254	1
Waterman Reservoir, Glocester	perch	65	1260	1
Olney Pond, Lincoln	sunfish	58	1254	1
Scituate Reservoir, Scituate stream from Barden Reservoir	perch	131	1260	1
Pawtuxet River Tributary, Cranston Print Works Pond	bluegill	2580	1254	1
Alton Jones Pond, West Greenwich	weeds	4	1254	1
	pumpkinseed	26	1254	1
	yellow perch	28	1248	1
Belleville Pond, North Kingstown	yellow perch	100	1254	1
Indian Lake, South Kingstown	perch	80	1254	1
Cards Pond, South Kingstown	herring	165	1254	1
Yawgoog Pond, Hopkinton	pickerel	419	1260	1
Locustville Pond, Hopkinton	yellow perch	34	1254	1
Yawgoo Pond, North Kingstown	weeds	ND		1
Hundred Acre Pond, South Kingstown	yellow perch	103	1260	1
	yellow perch	25	1254	1
Thirty Acre Pond, South Kingstown	yellow shiner	100	1254	1
	yellow perch	180	1254	1
Larkins Pond, South Kingstown	yellow perch	47	1254	1
	yellow perch	88	1248	1
Wordens Pond, South Kingstown	weeds	33	1242	1
	pumpkinseed	77	1260	1
	perch	40	1254	1
Tuckers Pond, South Kingstown	perch	36	1254	1
	yellow perch	62	1254	1
Brickyard Pond, Barrington	perch	60	1254	1
Wood River Pond, Richmond	weeds	10	1248	1
	perch	56	1254	1
Marine				
Narragansett Bay	winter flounder and skate	162-797	1254	2
Pawcatuck River, Watch Hill	shellfish	167	1254	3
Sakonnet River, Fogland Point	shellfish	<10	1254	3
Greenwich Bay, Sally Point	shellfish	<10	1254	3

References

1 Olney, 1972.

2 Sheehy, per comm.

3 Wong, per comm.

ND None detected

* Concentrations in fish based on whole fish wet weight

high PCB concentrations. Plant samples in the freshwater systems showed concentrations ranging from less than 10 to 77 ppb (wet weight). Sheehy (personal communication) collected winter flounder and skate from Narragansett Bay and found PCB concentrations from 162 to 797 ppb (wet weight). No PCB residues exceeding 1 ppm (wet weight) have been detected by the Rhode Island Department of Health in annual analyses of quahogs from upper Narragansett Bay (Siino, personal communication). Wong (personal communication) found that shellfish meat from Greenwich Bay and the Sakonnet River contained less than 10 ppb PCB, while one sample at Watch Hill contained 167 ppb. All these values are well under the FDA limit of 5 ppm (5000 ppb) for fish and shellfish, indicating that there is no serious hazard in respect to PCB contamination in seafood from Narragansett Bay.

Sediments

Freshwater Systems. The results of analyses of sediment samples from Rhode Island's freshwater systems in 1971 are shown in Table 4. These sediments contained up to 400 ppb PCB. The sediment samples generally had higher concentrations of PCBs than the water or biological samples, and represent the major sink for PCBs. Analysis of sediment samples at the mouth of the Pawtuxet River was not possible due to organic interference. However, an estimation of the upper limit for PCBs was 10 ppm (10,000 ppb).

Marine Systems. In September 1976, estuarine sediments at five stations in Narragansett Bay (Figure 2) were sampled and analyzed for PCBs (Paulson, unpublished). Data from this survey are shown in Table 5. The sediments in the vicinity of Fields Point (Stations 3 and 4) are considerably more contaminated with PCBs than those from the lower Bay (Station B), indicating that the Providence area is a major source of PCBs to the Bay. This is consistent with hydrocarbon and trace metal contamination of the Bay by greater Providence area sources. (Van Vleet and Quinn, 1977) Coastal Resources Center, in preparation). Both Allen Harbor and the Carrier Pier samples show PCB concentrations elevated above the West Passage sample, indicating possible sources of contamination in these areas. Olney's data (1972) suggest that the Pawtuxet River may be an additional source of PCBs.

Subsurface sediment samples were taken at the Fields Point stations. At Station 3, distinctly different sediment types were found in the upper and lower sections of the grab. The upper section consisted of black silt with a high PCB concentration, while the lower sample was coarser

Table 4. PCBs in Rhode Island Freshwater Sediments

Location	PCB concentration (ppb)*	Aroclor type	Ref.
Slatersville Reservoir, North Smithfield	103	1242	1
Nichols Pond, Burrillville	ND		1
Keech Pond, Glocester	286	1242	1
Waterman Reservoir, Glocester	155	1248	1
directly below orchard	210	1248	1
Woonasquatucket Reservoir, Smithfield	334	1242	1
Scituate Reservoir, Scituate, at Bridge 251, Rte. 116	73	1242	1
stream from Barden Reservoir	80	1254	1
Stream from Flat River Reservoir, Coventry	ND		1
Pond off Route 3, Coventry	220	1254	1
Pawtuxet River and Tributaries, Cranston, at mouth	Many peaks in chromatograms - Maximum Possible PCBs - 10 ppm		
at Elmwood Ave. Bridge	300	1254	1
Blackamore Pond	115	1254	1
Print Works Pond	55	1254	1
Alton Jones Pond, West Greenwich	159	1248	1
Belleville Pond, North Kingstown	ND		1
Annaquatucket River, North Kingstown, at Rte. 1	ND		1
Indian Lake, South Kingstown	40	1254	1
Locustville Pond, Hopkinton	76	1254	1
Yawgoo Pond, North Kingstown	400	1242	1
Hundred Acre Pond, South Kingstown, at middle	140	1254	1
at south end	91	1254	1
Thirty Acre Pond, South Kingstown, at north end	250	1248	1
below drain pipe	many peaks masking PCBs (petroleum?)		1
Wordens Pond, South Kingstown, at center	100	1242	1
Tuckers Pond, South Kingstown	105	1248	1
Wood River Pond, Richmond	300	1248**	1
Brickyard Pond, Barrington	263	1242	1
One Hundred Acre Cove, Barrington	20	1248	1
Melville Pond, Portsmouth, at edge	96	1254	1
at middle	40	1254	1
Easton Pond, Newport, at west side of dyke	100	1242	1
at east side of dyke	105	1242	1
Jamestown Reservoir, Jamestown	20	1248	1

References

1 Olney, 1972

ND None detected (less than 10 ppb)

* dry weight basis

** poor PCB match

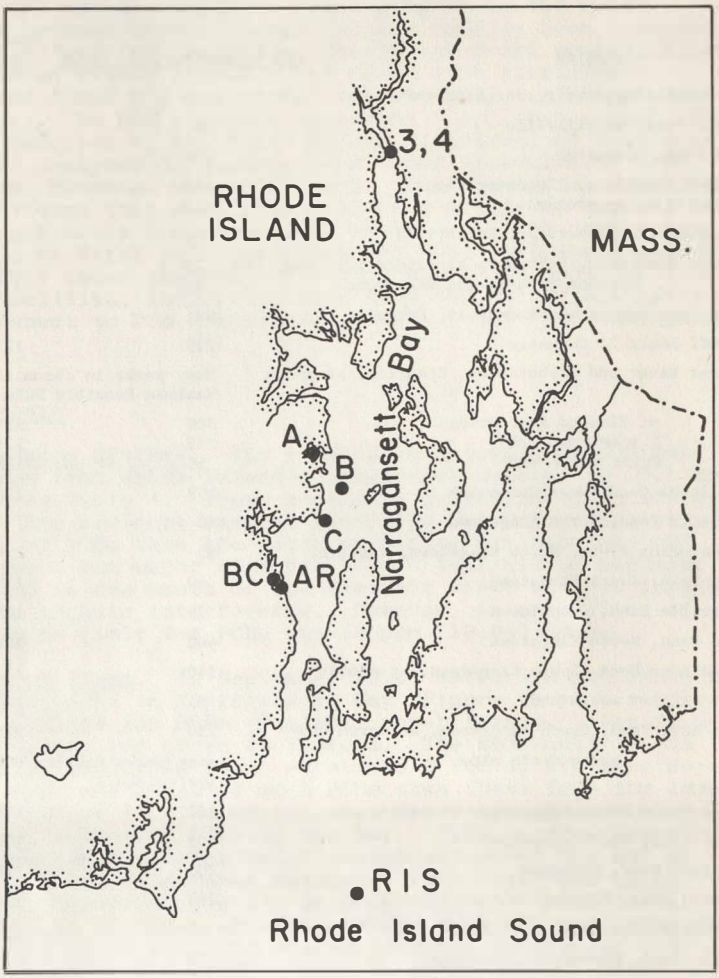

Figure 2. Station locations for marine sediments analyzed for PCBs. For references, see Table 5.

Table 5. PCBs in Rhode Island Marine Sediments

Station	Location	PCB concentration (ppb)*	Aroclor type	Depth	Ref.
A	Allen Harbor**	103	1254	0-2cm	1
B	West Passage, Narragansett Bay	30	1254	0-2cm	1
		32	1254	0-2cm	1
C	Carrier Pier, Quonset Point+	60	1254	0-2cm	1
3	Fields Point++	930	1254	0-2cm	1
		47	1254	9-11cm	1
4	Fields Point++	1100	1254	0-2cm	1
AR	Mouth of Annaquatucket River Estuary	115	1248		2
BC	Bissells Cove	less than 10			2
RIS	Rhode Island Sound	8.5		0-8cm	3
		3.1		8-18cm	3
		less than 0.1		18-28cm	3
		less than 0.1		28-38cm	3

References

1 Paulson

2 Olney, 1972

3 Boehm and Quinn, 1978

*Dry weight basis

**50 meters from the bulkhead of former Navy dump

+Near sewage outfall

++One mile downstream from Fields Point Sewage Treatment Plant, in the center of the shipping channel

and had a lower PCB concentration. A plausible explanation for this result is that the lower sample is older sediment, dating from before 1969, when the Army Corps of Engineers dredged the channel, while the upper section has been deposited since then and consists primarily of highly organic silt from the sewage plant. The calculated sedimentation rate of 1.5 cm/yr is consistent with sedimentation calculations based on the continuous dredging operation. Alternatively, this lower section could be an outcropping of coarse sediment due to a storm or other physical factors. At Station 4, the entire grab sample was homogeneous black silt and the analysis showed no change in PCB concentration with depth.

One sediment core from Rhode Island Sound has been analyzed for PCBs (Boehm and Quinn, 1978). The profile of PCB concentration is recorded in Table 5. The PCB concentration decreases with depth and no PCBs are detected in the 18 to 38 cm sections. The 0 to 8 cm section of this core cannot be directly compared to the surface samples from Narragansett Bay (Table 5), since the PCB concentration/depth relationship is not known accurately. The upper 2 cm of the Rhode Island Sound core may be higher in PCB content than the average of the entire 0 to 8 cm section.

Groundwater

Possible contamination of Rhode Island's groundwater by PCBs has not been thoroughly examined. Two groundwater samples were taken by EPA in April 1976 from the site of Sanitary Landfill, Inc., of Cranston, R.I., a company that previously accepted PCBs for disposal. PCBs were detected in one sample at a concentration of 2 ppb (Environmental Protection Agency, 1976a).

Sewage Sludge

Sludge samples from 14 municipal and 3 industrial sewage-treatment plants in Rhode Island have been analyzed for PCBs. For all but one of the municipal plants, PCB concentrations (Table 6) range from undetectable (< 10) to 3900 ppb (dry weight). The value for sludge from the Providence sewage-treatment plant (23,300 ppb) is greater by an order of magnitude. Two of the industrial sludges (from American Hoechst Corporation and Ciba-Geigy) were found in these analyses to contain considerably higher concentrations of PCBs, although neither plant uses PCBs in their processes. Sludge-disposal methods are given in Table 6. Most of the sludge generated in Rhode Island ultimately goes to landfills.

Table 6. PCBs in Sludge from Rhode Island Sewage Treatment Plants

Source	PCB concentration (ppb)*	Sludge disposal method
Municipal Plants		
Blackstone Valley District Treatment Plant	2500	Land site adjacent to plant
Bristol Sewage Treatment Plant	2130	Town landfill, Metacom Ave.
Cranston Treatment Plant	less than 10	Land site adjacent to plant
East Greenwich Treatment Plant	3900	Town landfill, Rocky Hollow Rd.
East Providence Treatment Plant	1540	Kent Heights Landfill, Wampanoag Trail
Narragansett-Scarborough Hills Treatment Plant	less than 10	Landfill, Red House Rd., Charlestown
Newport Sewage Treatment Plant	2780	Abandoned Quarry, Carroll Rd., South Newport
Providence Sewage Treatment Plant	23300	Sunshine Island, Fields Point Area, Providence
South Kingstown Sewage Treatment Plant	770	Rose Hill Road Landfill
Warren Sewage Treatment Plant	1840	Birch Swamp Road Landfill
Warwick Treatment Plant	3500	Removed by individuals from plant property
West Warwick Treatment Plant	less than 10	Land disposal on plant property
Westerly Sewage Treatment Plant	3840	Land disposal on plant property
Woonsocket Treatment Plant	490	Land site adjacent to plant
Industrial Plants		
American Hoechst Corp.	81300	Sylvestri Bros. Landfill, Johnston, and land application at Turf Farms
Ciba-Geigy	643000	Cranston Water Pollution Control Facility (see above)
Bostitch Division of Textron, Inc.		
zinc waste	less than 10	Disposal on Bostitch Property and at Truk-A-Way, Inc., landfill, Warwick
tumbling waste	120	

*Dry weight basis

From Keyes Associates, 1978. Areawide Sludge Management, Inventory Phase Report. Prepared for the "208" Areawide Water Quality Management Planning Project, R.I. Statewide Planning Program.

Assessment

PCBs do not appear to be a major pollution problem in Rhode Island's coastal waters. Sediments, as the major sink for PCBs in marine waters, provide an indication of the degree of contamination that has occurred in the system. Rhode Island sediments contain levels of PCBs several orders of magnitude less than those found in PCB problem areas such as Michigan, upstate New York, and New Bedford, Massachusetts, where fish have been found to contain PCBs at concentrations ten times the FDA limit for fish and shellfish. No fish or shellfish in Rhode Island have been found to exceed this limit, including shellfish from the upper Bay. At least one Narragansett Bay water sample analyzed in 1972 exceeded the proposed water-quality criterion of 1 ppt for PCBs. Newer analytical techniques could provide more accurate information about present water concentrations. A more complete array of sampling stations for both water and sediments would provide a clearer indication of the sources and distribution of PCBs.

No companies manufacturing PCBs or electrical equipment containing PCBs are located in Rhode Island (Environmental Protection Agency, 1976a). The Department of Health concluded in 1976 from a mail and telephone survey that no company in the state is generating PCB wastes. However, some landfills are receiving sewage sludge containing PCBs, and at least one Rhode Island landfill (Sanitary Landfill, Inc.) previously accepted PCB wastes for disposal. Leachate from these sites could contaminate surface or groundwaters with PCBs and should be monitored. More suitable methods for disposal of hazardous wastes generated in Rhode Island, such as PCB-contaminated sludge, are urgently needed.

The present restrictions on the use and disposal of PCBs will prevent the introduction of major new sources of PCB in the state. Thus, it is not expected that Rhode Island will have any of the major problems associated with electrical-equipment manufacturing plants; rather, PCB pollution will reflect domestic and non-electrical industrial use. Because of population and industrial distribution, it is likely that PCBs in the Narragansett Bay estuarine system will follow the general pattern of pollution: highest values in the Providence area, which decline down the Bay. Due to the relatively low concentration of PCBs in the Providence area and the association

with the sediments, the limited amount of data presently available strongly suggests that nowhere in Narragansett Bay are PCBs a major pollutant. However, because PCBs have been detected in all phases of the environment in Rhode Island and because they will continue to be included in solid wastes, sewage effluents, and sludge, their distribution and concentration should be monitored periodically, particularly in the vicinity of disposal sites. Edible fish and shellfish warrant particular attention in order to detect possible changes from presently non-hazardous concentrations of PCBs.

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