PCBs: Environmental Considerations

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PCBs: Environmental considerations

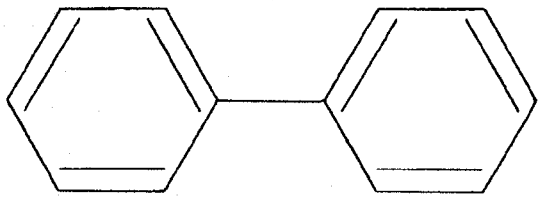
- PCBs in the environment
- PCBs in living organisms
- Health effects of concern

PCBs

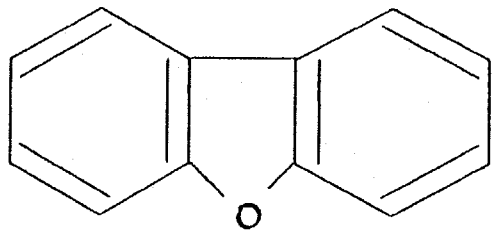
- Chlorine substitution
- Congeners
- Homologues
- Aroclors

Similarity of PCBs to dibenzofurans and dioxins

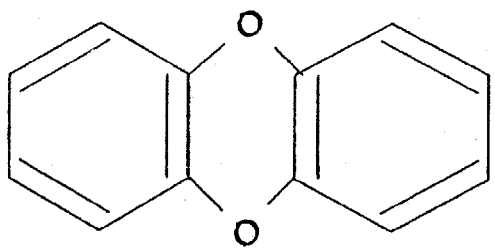
PCBs



Polychlorinated dibenzofurans



Polychlorinated dibenzo-*p*-dioxins



Typical composition of some Aroclor mixtures

	Aroclor 1016	1242	1248	1254	1260
Mono-CBs (%wt)	2	1	—	—	—
Di-CBs	19	13	1	—	—
Tri-CBs	57	45	21	1	—
Tetra-CBs	22	31	49	15	—
Penta-CBs	—	10	27	53	12
Hexa-CBs	—	—	2	26	42
Hepta-CBs	—	—	—	4	38
Octa-CBs	—	—	—	—	7
Nona-CBs	—	—	—	—	1
Deca-CB	—	—	—	—	—
Chlorine content (%)	41	42	48	54	60
Production, 1957–1977 (%)	13	52	7	16	11

"—" denotes less than 1%.
Sources: Adapted from U.S. EPA (1996), Cogliano (1998).

Environmental fate is related to chlorine substitution

1 ..... Chlorine content 10

Higher ..... Volatility ..... Low

Higher ..... Solubility in water ..... Low

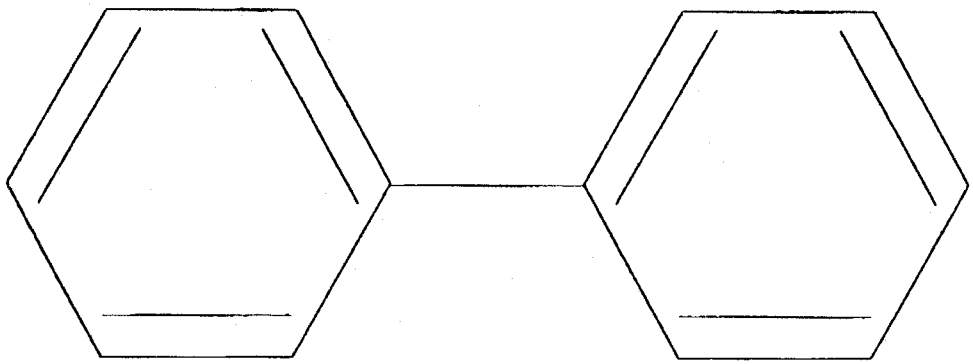
Low ..... Adsorption to soil and sediment ..... High

Low ..... Persistence in the environment ..... High

PCBs partition in the environment

Air —	Higher proportion of lower-chlorinated congeners
Water —	Higher proportion of lower-chlorinated congeners
Soil —	Higher proportion of higher-chlorinated congeners
Sediment —	Higher proportion of higher-chlorinated congeners

Metabolic fate is related to chlorine substitution



Oxidative metabolism is facilitated by the absence of chlorines in adjacent positions

PCBs bioaccumulate in the environment

- Each link in the food chain passes on congeners most difficult to eliminate
- PCB composition can be significantly altered

Which exposure pathways are of greatest concern?

- Bioaccumulated mixtures
  - Fish
  - Birds that eat fish
- Contaminated soil and sediment

PCBs and cancer

Mayes (1998) tested Aroclors 1016, 1242, 1254, and 1260 in rats

- All cause significant increases in liver cancer
- Some Aroclors increased thyroid cancer in males
- Potency differs for these mixtures

These mixtures contain overlapping groups of congeners that, together, span the range of congeners most often found in environmental mixtures

Conclusions

- All PCB mixtures can pose a risk of cancer
- There is a basis for distinguishing the cancer potential of different environmental mixtures

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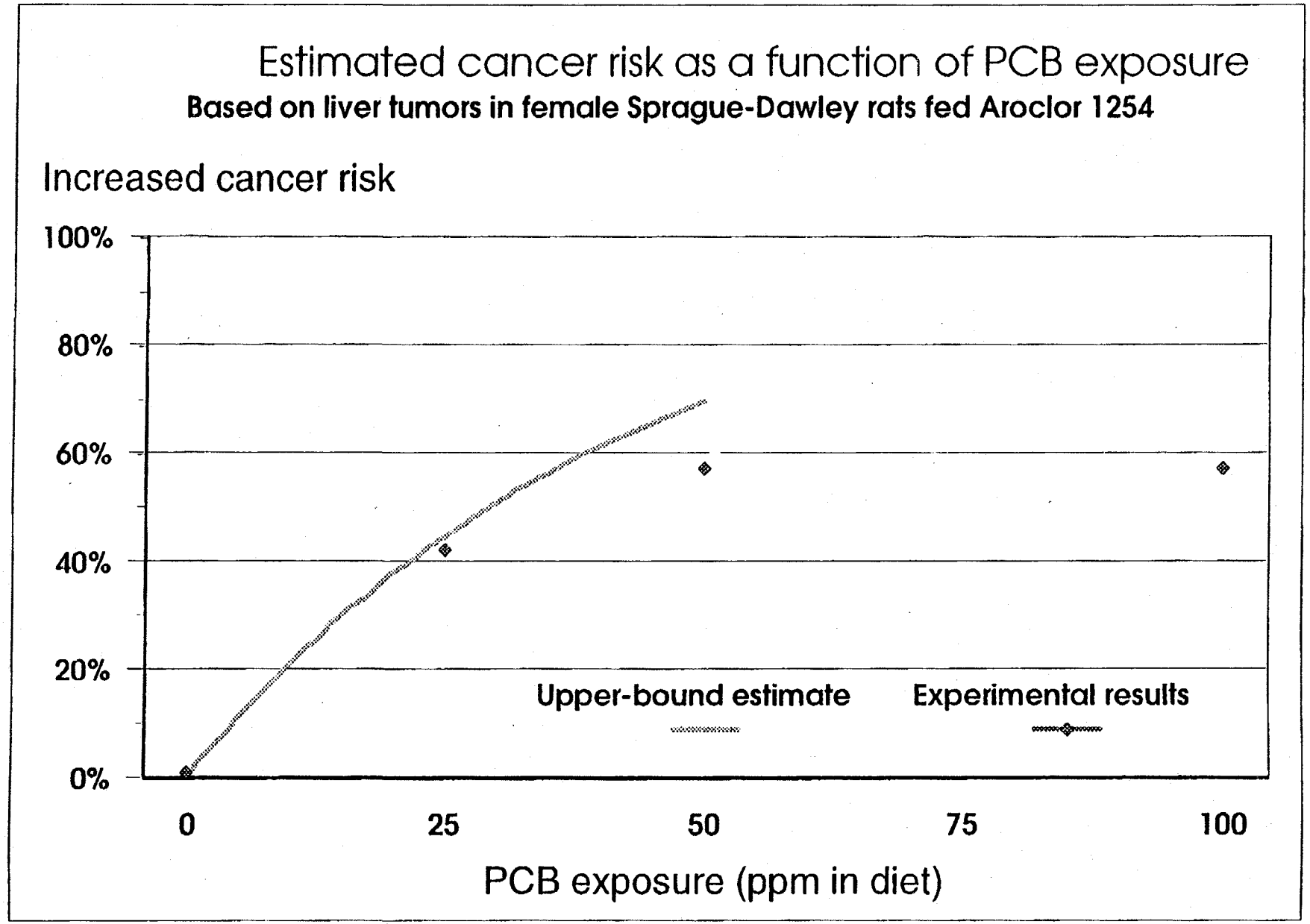
Liver tumor incidences from the 1996 rat study

Mixture	Dose	Females	Males
Aroclor 1260	Control	** 1/85 (1%)	** 7/98 (7%)
	25 ppm	10/49 (20%)	3/50 (6%)
	50 ppm	11/45 (24%)	6/49 (12%)
	100 ppm	24/50 (48%)	10/49 (20%)
Aroclor 1254	Control	** 1/85 (1%)	7/98 (7%)
	25 ppm	19/45 (42%)	4/48 (8%)
	50 ppm	28/49 (57%)	4/49 (8%)
	100 ppm	28/49 (57%)	6/47 (13%)
Aroclor 1242	Control	** 1/85 (1%)	7/98 (7%)
	50 ppm	11/49 (24%)	1/50 (2%)
	100 ppm	15/45 (33%)	4/46 (9%)
Aroclor 1016	Control	** 1/85 (1%)	7/98 (7%)
	50 ppm	1/48 (2%)	2/48 (4%)
	100 ppm	6/45 (13%)	2/50 (4%)
	200 ppm	5/50 (10%)	4/49 (8%)

**Statistically significant ($p<0.05$) by Cochran-Armitage trend test.
Hepatocellular adenomas, carcinomas, cholangiomas, or cholangiocarcinomas in rats alive when the first tumor was observed.
One control group supported all experiments.
Source: Brunner (*1996*), reported by U.S. EPA (*1996*); Mayes (*1998*).


Estimated cancer risk as a function of PCB exposure
Based on liver tumors in female Sprague-Dawley rats fed Aroclor 1254
Increased cancer risk
100%
80%
60%
40%
20%
0%
Upper-bound estimate
Experimental results
0
25
50
75
100
PCB exposure (ppm in diet)

Three tiers of environmental PCBs

HIGHEST RISK AND PERSISTENCE

- Food chain exposure
- Sediment or soil ingestion
- Dust or aerosol inhalation
- Early-life exposure (all pathways and mixtures)

LOWER RISK AND PERSISTENCE

- Ingestion of water-soluble congeners
- Inhalation of evaporated congeners
- Dermal exposure, if no absorption factor has been applied

LOWEST RISK AND PERSISTENCE

- Congener or homologue analyses verify that congeners with more than 4 chlorines comprise less than 1/2% of total PCBs

Less-than-lifetime exposure to the more persistent mixtures may pose disproportionately high risks

Mixture	Dose	Less-than-lifetime exposure	Lifetime exposure
Aroclor 1260	Control	** 1/85 (1%)	** 1/85 (1%)
	25 ppm	4/24 (17%)	10/49 (20%)
	50 ppm	3/24 (12%)	11/45 (24%)
	100 ppm	17/24 (71%)	24/50 (48%)
Aroclor 1254	Control	** 1/85 (1%)	** 1/85 (1%)
	25 ppm	5/24 (21%)	19/45 (42%)
	50 ppm	7/24 (29%)	28/49 (57%)
	100 ppm	6/24 (25%)	28/49 (57%)
Aroclor 1242	Control	** 1/85 (1%)	** 1/85 (1%)
	50 ppm	3/24 (12%)	11/49 (22%)
	100 ppm	6/24 (25%)	15/45 (33%)
Aroclor 1016	Control	1/85 (1%)	** 1/85 (1%)
	50 ppm	0/24 (0%)	1/48 (2%)
	100 ppm	0/24 (0%)	6/45 (13%)
	200 ppm	0/24 (0%)	5/50 (10%)

**Statistically significant ($p<0.05$) by Cochran-Armitage trend test.
Less-than-lifetime experiment involved rats dosed for 52 weeks and killed after 104 weeks.
Source: Brunner (*1996*), reported by U.S. EPA (*1996*).

Bioaccumulated PCBs may be more toxic and more persistent than the Aroclors

- In mink fed Great Lakes fish, reproductive toxicity and liver toxicity were greater than for other mink fed equivalent amounts of Aroclor 1254

- In monkeys fed a mixture representative of PCBs found in human milk, long-term behavioral impairments have been found

- In people eating Great Lakes fish, the rate of decline in serum PCB levels was much smaller than what has been reported for people exposed to Aroclors in the workplace

Noncancer effects of PCBs

PCBs have significant adverse health effects other than cancer, including

- Learning deficits
- Neurological effects
- Immune dysfunction
- Thyroid effects
- Hormonal effects

Recent studies raise new concerns about environmental exposure

Study of children whose mothers ate L. Michigan fish

3 days	Motor immaturity, ⇓ ability to quiet, ⇑ startle, ⇓ reflexes
7 months	⇓ short-term memory
4 years	⇓ verbal scale, ⇓ memory scale, ⇓ activity, ⇓ short-term memory, ⇓ visual discrimination
11 years	⇓ full-scale and verbal IQ, ⇓ work and reading comprehension, ⇓ memory and attention

Highest PCB group . . .

had average IQ 6 points below average

3x more likely to have low IQ

2x more likely to be 2 years behind in reading ability

Study of children whose mothers ate L. Ontario fish

Infancy	Abnormal reflexes, ⇑ startle, ⇑ tremor
12 months	⇓ habituation
36 months	⇓ general cognitive index

Study of PCBs from food (N. Carolina)

Early infancy	⇓ reflexes, ⇓ activity
6–12 months	⇓ psychomotor development
24 months	⇓ psychomotor development
3, 4, 5 years	No effect on motor or memory scales

Study of PCBs from food (Netherlands)

10, 21 days	⇓ reflexes, hypotonicity
3 months	⇓ psychomotor score, immunological changes
7 months	⇓ psychomotor score
18 months	⇓ psychomotor development, immunological changes
42 months	⇓ general cognitive scale, ⇓ high-level play, ⇑ non-play time, ⇑ reaction time, ⇑ withdrawn/depressed behavior, ⇑ prevalence of chicken pox, ⇓ antibodies to measles

These effects were seen at 3 ppb in blood serum

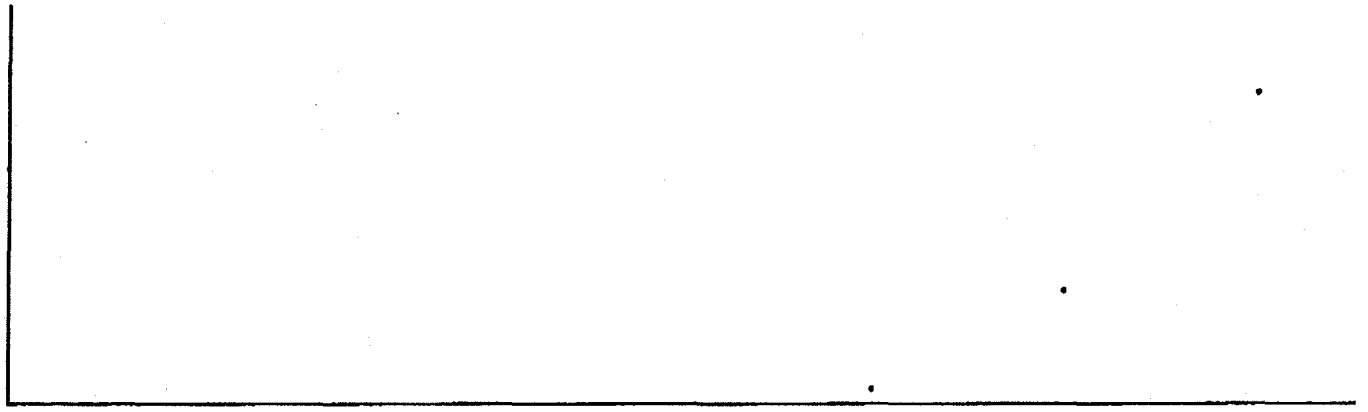
Studies of PCBs in monkeys

Independent studies in animals show that PCBs alone can cause effects analogous to those seen in the human studies, including

- ⇓ learning
- ⇓ memory
- ⇓ ability to adapt
- ⇓ ability to organize behavior
- ⇓ attention

These studies increase our confidence that the effects seen in the human studies can be attributed to PCBs

Noncancer reference dose

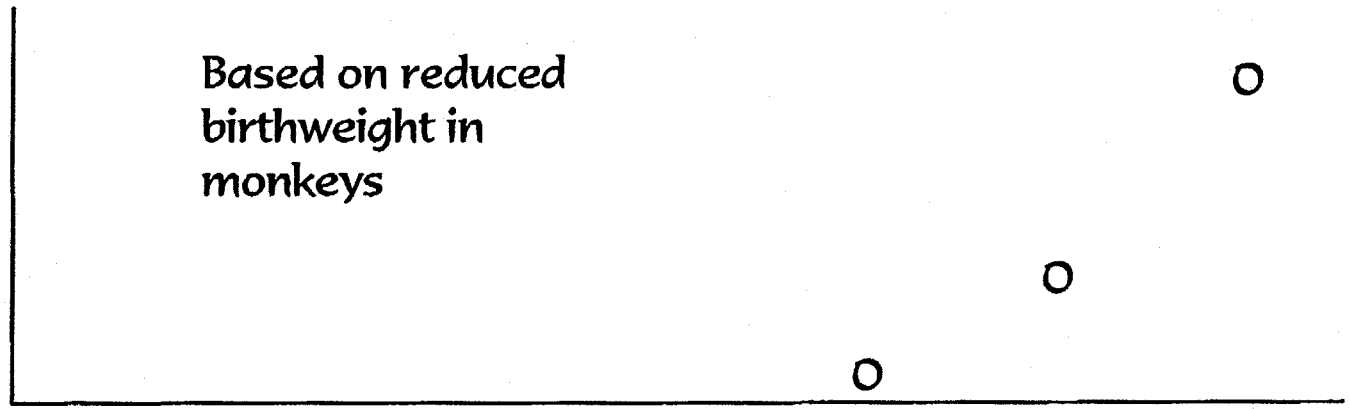


Human variability
Animal-to-human uncertainty
LOAEL-to-NOAEL uncertainty
Subchronic-to-chronic uncertainty
Database limitations
Modifying factor

for Aroclor 1254

Based on decreased antibody (IgG and IgM) response to sheep erythrocytes in monkeys				0
			0	
0.02	(300)		—	5 ug/kg-d
	10			
	3			
	3			
	3			
	—			
	—			

for Aroclor 1016



0.07 (100) 7 ug/kg-d 28 ug/kg-d

3
3
1
3
3

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Summary

- PCB mixtures are altered in the environment — in some cases increasing the mixture's persistence and toxicity
- Principal exposures of concern are bioaccumulated PCBs and PCBs attached to soils or sediments
- Evidence is strong that environmental PCBs pose a risk of cancer
- Evidence is mounting that noncancer effects, especially learning deficits and neurological effects, have occurred from environmental PCB exposure

WHAT CAN YOU DO?

- Pay attention to fish advisories

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