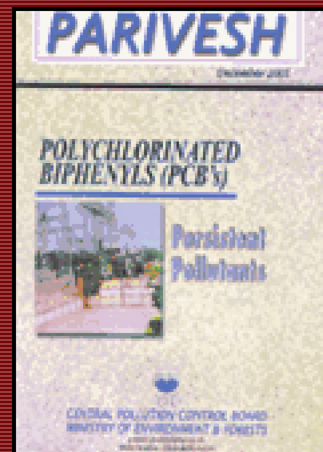
Parivesh

A News Letter from ENVIS Centre - Central Pollution Control Board

Contents



Archives Home

Parivesh

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POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

Polychlorinated Biphenyls (PCB's) - An Introduction

Polychlorinated Biphenyls (PCB's) are a range of substances consisting of a biphenyl molecule with or without alkyl or aryl substituents, in which more than one chlorine atom is substituted in the biphenyl nucleus. It is believed that PCB's do not occur naturally. They are resistant to chemical and biochemical process. PCB's are excellent dielectrics, stable to thermal, chemical and biological degradation and are fire resistant. These have been in use commercially, since 1930 as dielectric and heat exchange fluids and in a variety of other applications. Their thermal stability, chemical stability e.g. general inertness to oxidation and hydrolysis and dielectric properties have made these very useful in a variety of industrial applications. PCB's were developed as high boiling point stable, heat-transfer fluids for use in transformers and heat exchangers. Other major uses of PCB's included hydraulic fluids, plasticizers, carbonless carbon paper, inks, lubricants, waxes, cutting oils, and adhesives. They have been used as coolant – insulation fluids in capacitors and transformers, as agents for impregnating cotton and asbestos, in braided insulation of electrical wiring; as high – pressure hydraulic fluids; as heat transfer agents (Gustafson, 1970). In United States of America approximately 50% of total production was used in capacitors and transformers and 20% as plasticizers between 1930 to 1970. The degree of chlorination of PCB's being adjusted according to the intended use.

The PCB's had been discovered before the turn of 19^{th} century and were first produced in 1929 as Aroclor. The bulk of commercial Aroclors consists of about 50 PCB's isomers. The commercial mixtures of PCB's in term of Aroclor is designated by four digit numbers of which the first pair (e.g. 12 in Aroclor 1242) designate the category of PCB's and the second pair of digits designate the approximate percentage of chlorine, e.g. Aroclor 1242 has 42% chlorine, equivalent to the composition $C_{12}H_7Cl_3$ and is a liquid with a boiling point of 38^0C, while Aroclor 1260 is 60% Chlorine, equivalent to $C_{12}H_4Cl_6$ and is a solid. PCB's are very resistant to chemical and bio-chemical degradation, their stability increases with the degree of chlorination and therefore they persist in the environment. Individual PCB isomers can differ sharply in their persistence, with the monochlorinated compounds generally being quite biodegradable. PCB's with three or more chlorines on each phenyl rings are generally quite persistent, highly lipophilic (soluble to 10% in fat), water soluble, and extremely stable in the environment.

PCB's are widely distributed in the environment throughout the world, and are persistent and accumulative in food web. Polychlorinated biphenyls have been found in environmental and biological samples at many locations and tend to accumulate in sediments, soils and biota (Pal *et.al.*, 1980). The widespread distribution of PCB's has been attributed to their volatilization or aerosol formation and atmospheric transport followed by wet or dry deposition.

PCB's are practically insoluble in water, whereas they dissolve easily in hydrocarbons, fats and other organic compounds and they are readily absorbed by fatty tissues. The risk of human exposure to PCB's had been excessively large due to their persistent nature and have resulted due to the consumption of contaminated food, as well as from inhalation and skin absorption in work environment. PCB's accumulated in the fatty tissues of humans and other animals are the cause of toxic effects. The skin and liver are the major sites of PCB's cytological effects, but the gastrointestinal tract, the immune system and the nervous system are also the major targets.

HOME NEXT

Back to Content

Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

NOMENCLATURE OF PCB's

PCB's are the class of synthetic chlorinated organic compounds constituting biphenyl as the basic structural unit. Chlorination of the group can produce 209 possible chlorobiphenyls (congeners) substituted with 1 to 10 chlorine atoms. Systematic numbering and nomenclature of these chlorobiphenyls according to Ballschmiter and Zell are given in the Table 1. According to the IUPAC nomenclature of organic chemistry the structure of PCB's constitute two rings, one ring in the biphenyl assembly is assigned unprimed number and the other biphenyl assembly as primed numbers (Fig. 1).

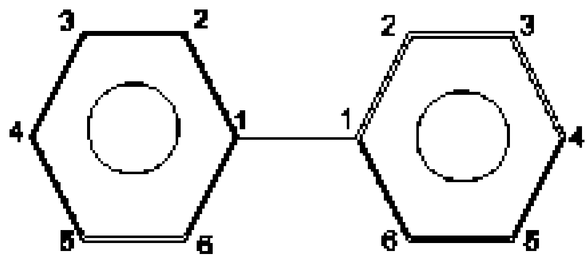

Fig. 1: Structure and numbering pattern of PCB's in biphenyl ring system

As per the IUPAC system, the order for assigning priorities to the substituents in the ring assembly, as Chlorine in PCB's are:

- Unprimed number is assigned lower order than the corresponding primed number as 2 vs. 2'.
- Lower number is assigned to a point of attachment in equivalent position, as 2 vs. 6, for the substituents in one of the ortho positions.
- When the number of substituents in the two ring systems is the same, unprimed numbers are assigned to the ring system with smaller numbered substituents.

The increased use of PCB's as important industrial chemicals for use as non-flammable oils in a host of products gave birth to a series of commercially available raw materials marketed under various trade names. The trade names of commonly used PCB based commercial/industrial dielectric fluids are presented in Table 2.

Table 1 Polychlorinated Biphenyl (PCB's) congeners/isomers and their nomenclature as per IUPAC System

Group	BZ* No.	PCB Congener/Isomers	CAS Registry No.
Monochloro-biphenyl	BZ-1	2-Chlorobiphenyl	2051-60-7
	BZ-2	3-Chlorobiphenyl	2051-61-8
	BZ-3	4-Chlorobiphenyl	2051-62-9
Dichloro-biphenyl	BZ-4	2,2'-Dichlorobiphenyl	13029-08-8
	BZ-5	2,3-Dichlorobiphenyl	16605-91-7
	BZ-6	2,3'-Dichlorobiphenyl	25569-80-6
	BZ-7	2,4-Dichlorobiphenyl	33284-50-3
	BZ-8	2,4'-Dichlorobiphenyl	34883-43-7
	BZ-9	2,5-Dichlorobiphenyl	34883-39-1
	BZ-10	2,6-Dichlorobiphenyl	33146-45-1
	BZ-11	3,3'-Dichlorobiphenyl	2050-67-1
	BZ-12	3,4-Dichlorobiphenyl	2974-92-7
	BZ-13	3,4'-Dichlorobiphenyl	2974-90-5
	BZ-14	3,5-Dichlorobiphenyl	34883-41-5
	BZ-15	4,4'-Dichlorobiphenyl	2050-68-2

Trichloro-biphenyl	BZ-16	2,2',3-Trichlorobiphenyl	38444-78-9
	BZ-17	2,2',4-Trichlorobiphenyl	37680-66-3
	BZ-18	2,2',5-Trichlorobiphenyl	37680-65-2
	BZ-19	2,2',6-Trichlorobiphenyl	38444-73-4
	BZ-20	2,3,3'-Trichlorobiphenyl	38444-84-7
	BZ-21	2,3,4-Trichlorobiphenyl	55702-46-0
	BZ-22	2,3,4'-Trichlorobiphenyl	38444-85-8
	BZ-23	2,3,5-Trichlorobiphenyl	55720-44-0
	BZ-24	2,3,6-Trichlorobiphenyl	55702-45-9
	BZ-25	2,3',4-Trichlorobiphenyl	55712-37-3
	BZ-26	2,3',5-Trichlorobiphenyl	38444-81-4
	BZ-27	2,3',6-Trichlorobiphenyl	38444-76-7
	BZ-28	2,4,4'-Trichlorobiphenyl	7012-37-5
	BZ-29	2,4,5-Trichlorobiphenyl	15862-07-4
	BZ-30	2,4,6-Trichlorobiphenyl	35693-92-6
	BZ-31	2,4',5-Trichlorobiphenyl	16606-02-3
	BZ-32	2,4',6-Trichlorobiphenyl	38444-77-4
	BZ-33	2',3,4-Trichlorobiphenyl	38444-86-9
	BZ-34	2',3,5-Trichlorobiphenyl	37680-68-5
	BZ-35	3,3',4-Trichlorobiphenyl	37680-69-6
	BZ-36	3,3',5-Trichlorobiphenyl	38444-87-0
	BZ-37	3,4,4'-Trichlorobiphenyl	38444-90-5
	BZ-38	3,4,5-Trichlorobiphenyl	53555-66-1
	BZ-39	3,4',5-Trichlorobiphenyl	38444-88-1
Tetrachloro-biphenyl	BZ-40	2,2',3,3'-Tetrachlorobiphenyl	38444-93-8
	BZ-41	2,2',3,4-Tetrachlorobiphenyl	52663-59-9
	BZ-42	2,2',3,4'-Tetrachlorobiphenyl	36559-22-5
	BZ-43	2,2',3,5-Tetrachlorobiphenyl	70362-46-8
	BZ-44	2,2',3,5'-Tetrachlorobiphenyl	41464-39-5
	BZ-45	2,2',3,6-Tetrachlorobiphenyl	70362-45-7
	BZ-46	2,2',3,6'-Tetrachlorobiphenyl	41464-47-5
	BZ-47	2,2',4,4'-Tetrachlorobiphenyl	2437-79-8
	BZ-48	2,2',4,5-Tetrachlorobiphenyl	70362-47-9
	BZ-49	2,2',4,5'-Tetrachlorobiphenyl	41464-40-8
	BZ-50	2,2',4,6-Tetrachlorobiphenyl	62796-65-0
	BZ-51	2,2',4,6'-Tetrachlorobiphenyl	68194-04-7
	BZ-52	2,2',5,5'-Tetrachlorobiphenyl	35693-99-3
	BZ-53	2,2',5,6'-Tetrachlorobiphenyl	41464-41-9
	BZ-54	2,2',6,6'-Tetrachlorobiphenyl	15968-05-5
	BZ-55	2,3,3',4-Tetrachlorobiphenyl	74338-24-2
	BZ-56	2,3,3',4'-Tetrachlorobiphenyl	41464-43-1
	BZ-57	2,3,3',5-Tetrachlorobiphenyl	70424-67-8
	BZ-58	2,3,3',5'-Tetrachlorobiphenyl	41464-49-7
	BZ-59	2,3,3',6-Tetrachlorobiphenyl	74472-33-6
	BZ-60	2,3,4,4'-Tetrachlorobiphenyl	33025-41-1
	BZ-61	2,3,4,5-Tetrachlorobiphenyl	33284-53-6
	BZ-62	2,3,4,6-Tetrachlorobiphenyl	54230-22-7
Group	**BZ* No.**	**PCB Congener/Isomers**	**CAS Registry No.**
Tetrachloro-biphenyl	BZ-63	2,3,4',5-Tetrachlorobiphenyl	74472-34-7
	BZ-64	2,3,4',6-Tetrachlorobiphenyl	52663-58-8
	BZ-65	2,3,5,6-Tetrachlorobiphenyl	33284-54-7
	BZ-66	2,3',4,4'-Tetrachlorobiphenyl	32598-10-0
	BZ-67	2,3',4,5-Tetrachlorobiphenyl	73557-53-8
	BZ-68	2,3',4,5'-Tetrachlorobiphenyl	73575-52-7
	BZ-69	2,3',4,6-Tetrachlorobiphenyl	60233-24-1
	BZ-70	2,3',4',5-Tetrachlorobiphenyl	32598-11-1
	BZ-71	2,3',4',6-Tetrachlorobiphenyl	41464-46-4
	BZ-72	2,3',5,5'-Tetrachlorobiphenyl	41464-42-0
	BZ-73	2,3',5',6-Tetrachlorobiphenyl	74338-23-1
	BZ-74	2,4,4',5-Tetrachlorobiphenyl	32690-93-0
	BZ-75	2,4,4',6-Tetrachlorobiphenyl	32598-12-2

	BZ-76	2’,3,4,5-Tetrachlorobiphenyl	70362-48-0
	BZ-77	3,3’,4,4’-Tetrachlorobiphenyl	32598-13-3
	BZ-78	3,3’,4,5-Tetrachlorobiphenyl	70362-49-1
	BZ-79	3,3’,4,5’-Tetrachlorobiphenyl	41464-48-6
	BZ-80	3,3’,5,5’-Tetrachlorobiphenyl	33284-52-5
	BZ-81	3,4,4’,5-Tetrachlorobiphenyl	70362-50-4
Pentachloro-biphenyl	BZ-82	2,2’,3,3’,4-Pentachlorobiphenyl	52663-62-4
	BZ-83	2,2’,3,3’,5-Pentachlorobiphenyl	60145-20-2
	BZ-84	2,2’,3,3’,6-Pentachlorobiphenyl	52663-60-2
	BZ-85	2,2’,3,4,4’-Pentachlorobiphenyl	65510-45-4
	BZ-86	2,2’,3,4,5-Pentachlorobiphenyl	55312-69-1
	BZ-87	2,2’,3,4,5’-Pentachlorobiphenyl	38380-02-8
	BZ-88	2,2’,3,4,6-Pentachlorobiphenyl	55215-17-3
	BZ-89	2,2’,3,4,6’-Pentachlorobiphenyl	73575-57-2
	BZ-90	2,2’,3,4’,5-Pentachlorobiphenyl	68194-07-0
	BZ-91	2,2’,3,4’,6-Pentachlorobiphenyl	68194-05-8
	BZ-92	2,2’,3,5,5’-Pentachlorobiphenyl	52663-61-3
	BZ-93	2,2’,3,5,6-Pentachlorobiphenyl	73575-56-1
	BZ-94	2,2’,3,5,6’-Pentachlorobiphenyl	73575-55-0
	BZ-95	2,2’,3,5’,6-Pentachlorobiphenyl	38379-99-6
	BZ-96	2,2’,3,6,6’-Pentachlorobiphenyl	73575-54-9
	BZ-97	2,2’,3’,4,5-Pentachlorobiphenyl	41464-51-1
	BZ-98	2,2’,3’,4,6-Pentachlorobiphenyl	60233-25-2
	BZ-99	2,2’,4,4’,5-Pentachlorobiphenyl	38380-01-7
	BZ-100	2,2’,4,4’,6-Pentachlorobiphenyl	39485-83-1
	BZ-101	2,2’,4,5,5’-Pentachlorobiphenyl	37680-73-2
	BZ-102	2,2’,4,5,6’-Pentachlorobiphenyl	68194-06-9
	BZ-103	2,2’,4,5’,6-Pentachlorobiphenyl	60145-21-3
	BZ-104	2,2’,4,6,6’-Pentachlorobiphenyl	56558-16-8
	BZ-105	2,3,3’,4,4’-Pentachlorobiphenyl	32598-14-4
	BZ-106	2,3,3’,4,5-Pentachlorobiphenyl	70424-69-0
	BZ-107	2,3,3’,4’,5-Pentachlorobiphenyl	70424-68-9
	BZ-108	2,3,3’,4,5’-Pentachlorobiphenyl	70362-41-3
	BZ-109	2,3,3’,4,6-Pentachlorobiphenyl	74472-35-8
	BZ-110	2,3,3’,4’,6-Pentachlorobiphenyl	38380-03-9
	BZ-111	2,3,3’,5,5’-Pentachlorobiphenyl	39635-32-0
	BZ-112	2,3,3’,5,6-Pentachlorobiphenyl	74472-36-9
	BZ-113	2,3,3’,5’,6-Pentachlorobiphenyl	68194-10-5
	BZ-114	2,3,4,4’,5-Pentachlorobiphenyl	74472-37-0
	BZ-115	2,3,4,4’,6-Pentachlorobiphenyl	74472-38-1
	BZ-116	2,3,4,5,6-Pentachlorobiphenyl	18259-05-7
	BZ-117	2,3,4’,5,6-Pentachlorobiphenyl	68194-11-6
	BZ-118	2,3’,4,4’,5-Pentachlorobiphenyl	31508-00-6
	BZ-119	2,3’,4,4’,6-Pentachlorobiphenyl	56558-17-9
	BZ-120	2,3’,4,5,5’-Pentachlorobiphenyl	68194-12-7
	BZ-121	2,3’,4,5’,6-Pentachlorobiphenyl	56558-18-0
	BZ-122	2’,3,3’,4,5-Pentachlorobiphenyl	76842-07-4
	BZ-123	2’,3,4,4’,5-Pentachlorobiphenyl	65510-44-3
	BZ-124	2’,3,4,5,5’-Pentachlorobiphenyl	70424-70-3
	BZ-125	2’,3,4,5,6’-Pentachlorobiphenyl	74472-39-2
	BZ-126	3,3’,4,4’,5-Pentachlorobiphenyl	57465-28-8
	BZ-127	3,3’,4,5,5’-Pentachlorobiphenyl	39635-33-1
Group	**BZ* No.**	**PCB Congener/Isomers**	**CAS Registry No.**
Hexachloro-biphenyl	BZ-128	2,2’,3,3’,4,4’-Hexachlorobiphenyl	38380-07-3
	BZ-129	2,2’,3,3’,4,5-Hexachlorobiphenyl	55215-18-4
	BZ-130	2,2’,3,3’,4,5’-Hexachlorobiphenyl	52663-66-8
	BZ-131	2,2’,3,3’,4,6-Hexachlorobiphenyl	61798-70-7
	BZ-132	2,2’,3,3’,4,6’-Hexachlorobiphenyl	38380-05-1
	BZ-133	2,2’,3,3’,5,5’-Hexachlorobiphenyl	35694-04-3
	BZ-134	2,2’,3,3’,5,6-Hexachlorobiphenyl	52704-70-8

	BZ-135	2,2',3,3',5,6'-Hexachlorobiphenyl	52744-13-5
	BZ-136	2,2',3,3',6,6'-Hexachlorobiphenyl	38411-22-2
	BZ-137	2,2',3,4,4',5-Hexachlorobiphenyl	35694-06-5
	BZ-138	2,2',3,4,4',5'-Hexachlorobiphenyl	35065-28-2
	BZ-139	2,2',3,4,4',6-Hexachlorobiphenyl	56030-56-9
	BZ-140	2,2',3,4,4',6'-Hexachlorobiphenyl	59291-64-4
	BZ-141	2,2',3,4,5,5'-Hexachlorobiphenyl	52712-04-6
	BZ-142	2,2',3,4,5,6-Hexachlorobiphenyl	41411-61-4
	BZ-143	2,2',3,4,5,6'-Hexachlorobiphenyl	68194-15-0
	BZ-144	2,2',3,4,5',6-Hexachlorobiphenyl	68194-14-9
	BZ-145	2,2',3,4,6,6'-Hexachlorobiphenyl	74472-40-5
	BZ-146	2,2',3,4',5,5'-Hexachlorobiphenyl	51908-16-8
	BZ-147	2,2',3,4',5,6-Hexachlorobiphenyl	68194-13-8
	BZ-148	2,2',3,4',5,6'-Hexachlorobiphenyl	74472-41-6
	BZ-149	2,2',3,4',5',6-Hexachlorobiphenyl	38380-04-0
	BZ-150	2,2',3,4',6,6'-Hexachlorobiphenyl	68194-08-1
	BZ-151	2,2',3,5,5',6-Hexachlorobiphenyl	52663-63-5
	BZ-152	2,2',3,5,6,6'-Hexachlorobiphenyl	68194-09-2
	BZ-153	2,2',4,4',5,5'-Hexachlorobiphenyl	35065-27-1
	BZ-154	2,2',4,4',5,6'-Hexachlorobiphenyl	60145-22-4
	BZ-155	2,2',4,4',6,6'-Hexachlorobiphenyl	33979-03-2
	BZ-156	2,3,3',4,4',5-Hexachlorobiphenyl	38380-08-4
	BZ-157	2,3,3',4,4',5'-Hexachlorobiphenyl	69782-90-7
	BZ-158	2,3,3',4,4',6-Hexachlorobiphenyl	74472-42-7
	BZ-159	2,3,3',4,5,5'-Hexachlorobiphenyl	39635-35-3
	BZ-160	2,3,3',4,5,6-Hexachlorobiphenyl	41411-62-5
	BZ-161	2,3,3',4,5',6-Hexachlorobiphenyl	74474-43-8
	BZ-162	2,3,3',4',5,5'-Hexachlorobiphenyl	39635-34-2
	BZ-163	2,3,3',4',5,6-Hexachlorobiphenyl	74472-44-9
	BZ-164	2,3,3',4',5',6-Hexachlorobiphenyl	74472-45-0
	BZ-165	2,3,3',5,5',6-Hexachlorobiphenyl	74472-46-1
	BZ-166	2,3,4,4',5,6-Hexachlorobiphenyl	41411-63-6
	BZ-167	2,3',4,4',5,5'-Hexachlorobiphenyl	52663-72-6
	BZ-168	2,3',4,4',5',6-Hexachlorobiphenyl	59291-65-5
	BZ-169	3,3',4,4',5,5'-Hexachlorobiphenyl	32774-16-6
Heptachloro-biphenyl	BZ-170	2,2',3,3',4,4',5-Heptachlorobiphenyl	35065-30-6
	BZ-171	2,2',3,3',4,4',6-Heptachlorobiphenyl	52663-71-5
	BZ-172	2,2',3,3',4,5,5'-Heptachlorobiphenyl	52663-74-8
	BZ-173	2,2',3,3',4,5,6-Heptachlorobiphenyl	68194-16-1
	BZ-174	2,2',3,3',4,5,6'-Heptachlorobiphenyl	38411-25-5
	BZ-175	2,2',3,3',4,5',6-Heptachlorobiphenyl	40186-70-7
	BZ-176	2,2',3,3',4,6,6'-Heptachlorobiphenyl	52663-65-7
	BZ-177	2,2',3,3',4',5,6-Heptachlorobiphenyl	52663-70-4
	BZ-178	2,2',3,3',5,5',6-Heptachlorobiphenyl	52663-67-9
	BZ-179	2,2',3,3',5,6,6'-Heptachlorobiphenyl	52663-64-6
	BZ-180	2,2',3,4,4',5,5'-Heptachlorobiphenyl	35065-29-3
	BZ-181	2,2',3,4,4',5,6-Heptachlorobiphenyl	74472-47-2
	BZ-182	2,2',3,4,4',5,6'-Heptachlorobiphenyl	60145-23-5
	BZ-183	2,2',3,4,4',5',6-Heptachlorobiphenyl	52663-69-1
	BZ-184	2,2',3,4,4',6,6'-Heptachlorobiphenyl	74472-48-3
	BZ-185	2,2',3,4,5,5',6-Heptachlorobiphenyl	52712-05-7
	BZ-186	2,2',3,4,5,6,6'-Heptachlorobiphenyl	74472-49-4
	BZ-187	2,2',3,4',5,5',6-Heptachlorobiphenyl	52663-68-0
	BZ-188	2,2',3,4',5,6,6'-Heptachlorobiphenyl	74487-85-7
	BZ-189	2,3,3',4,4',5,5'-Heptachlorobiphenyl	39635-31-9
	BZ-190	2,3,3',4,4',5,6-Heptachlorobiphenyl	41411-64-7
	BZ-191	2,3,3',4,4',5',6-Heptachlorobiphenyl	74472-50-7
	BZ-192	2,3,3',4,5,5',6-Heptachlorobiphenyl	74472-51-8
	BZ-193	2,3,3',4',5,5',6-Heptachlorobiphenyl	69782-91-8
	BZ* No.	**PCB Congener/Isomers**	**CAS Registry No.**

Group			
Octachloro-biphenyl	BZ-194	2,2',3,3',4,4',5,5'-Octachlorobiphenyl	35694-08-7
	BZ-195	2,2',3,3',4,4',5,6-Octachlorobiphenyl	52663-78-2
	BZ-196	2,2',3,3',4,4',5',6-Octachlorobiphenyl	42740-50-1
	BZ-197	2,2',3,3',4,4',6,6'-Octachlorobiphenyl	33091-17-7
	BZ-198	2,2',3,3',4,5,5',6-Octachlorobiphenyl	68194-17-2
	BZ-199	2,2',3,3',4,5,6,6'-Octachlorobiphenyl	52663-73-7
	BZ-200	2,2',3,3',4,5',6,6'-Octachlorobiphenyl	40186-71-8
	BZ-201	2,2',3,3',4,5,5',6'-Octachlorobiphenyl	52663-75-9
	BZ-202	2,2',3,3',5,5',6,6'-Octachlorobiphenyl	2136-99-4
	BZ-203	2,2',3,4,4',5,5',6-Octachlorobiphenyl	52663-76-0
	BZ-204	2,2',3,4,4',5,6,6'-Octachlorobiphenyl	74472-52-9
	BZ-205	2,3,3',4,4',5,5',6-Octachlorobiphenyl	74472-53-0
Nonachloro-biphenyl	BZ-206	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	40186-72-9
	BZ-207	2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl	52663-79-3
	BZ-208	2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl	52663-77-1
Decachloro-biphenyl	BZ-209	2,2',3,3',4,4',5,5',6,6'- Decachlorobiphenyl	2051-24-3

* BZ : Ballschmiter and Zell Number

Table 2 Commercial Trade names of PCB's/PCT's based Commercial/Industrial Dielectric Fluids

Country	Commercial Name	Remarks
United Kingdom (U.K.)	Aroclor	-
	Pyroclor	-
	Santothern*	Used for Heat Transfer
USA	Aroclor	-
	Inerteen	-
	Pyranol	-
	Therminol FR*	Used for Heat Transfer
	Pydraul	Used for Hydraulic Application before 1972
France	Pyralene	-
	Phenoclor	-
Germany	Clophen	-
Italy	Apirolio	-
	Fenoclor	-
Japan	Kaneclor	-
Russia (Earlier USSR)	Solvol	-

* FR Series of Santothern and Therminol contain PCB's and were used prior to 1972.

BACK HOME NEXT

Back to Content

Parivesh

A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

ANALOGOUS COMPOUNDS OF PCB's - POLYCHLORINATED TERPHENYLS (PCT's)

The analogous compounds of PCB's are alkylated chlorobiphenyls and polychlorinated terphenyls and higher phenyls. The properties of these compounds are very close to PCB's and depend on degree of chlorination.

The Polychlorinated Terphenyls (PCT's) can be represented as $C_{18}H_{14-n}Cl_n$ in which `n' is the number of chlorine atoms, which can range from 1 to 14. The physical and chemical properties of PCT's are similar to whose of PCB's and depend on the degree of chlorination. Similar to the PCB's the Polychlorinated terphenyls are not marketed as composition specification, but based on their physical properties, which depend on degree of chlorination. The trade names of PCT's are generally similar to those given for PCB's. However, in the Aroclor series, terphenyls are indicated by 54 at the first two places of the four-digit code. The PCT's are commercially known as Kaneclor in Japan.

BACK HOME NEXT

Back to Content

Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

PHYSICO-CHEMICAL CHARACTERISTICS OF PCB'S

PCB's are the mixture of aromatic chemicals, manufactured by the chlorination of biphenyls in the presence of a suitable catalyst. The chemical formula of PCB's can be presented as $C_{12}H_{10-n}Cl_n$, where `n' is a number of chlorine atoms within the range of 1-10. The relative molecular mass of PCB compounds depend on the degree of substitution. Monochlorobiphenyl has a relative molecular mass of 188, while completely chlorinated biphenyl [$C_{12}Cl_{10}$] has relative molecular mass of 494. Some physical and chemical characteristics of PCB's are presented in Table 3.

Table 3 Physico-chemical properties of selected Aroclors

(Polychlorinated Biphenyls)

Aroclor Compound	Water solubility (mg/l) 25 ^{0}C	Vapour Pressure (torr) 25 ^{0}C	Density (g/cm^3) 25 ^{0}C	Appearance	Boiling point (^{0}C) at 750 torr
1016	0.42	4.0×10^{-4}	1.33	Clear oil	325-356
1221	0.59	6.7×10^{-3}	1.15	Clear oil	275-320
1232	0.45	4.1×10^{-3}	1.24	Clear oil	290-325
1242	0.24	4.1×10^{-3}	1.35	Clear oil	325-366
1248	0.054	4.9×10^{-4}	1.41	Clear oil	340-375
1254	0.021	7.7×10^{-5}	1.50	Light yellow viscous oil	365-390
1260	0.0027	4.0×10^{-5}	1.58	Light yellow sticky resin	385-420

Source: IARC (1978), WHO/EURO (1987).

All congeners of PCB's are lipophilic and have very low water solubility. Solubility of PCB's in water and in organic solvents, such as lipids, greatly influences their transport and persistence in the environment and this may be the reason that these compounds easily enter the food chain and accumulate in the fatty tissues. Solubility of PCB's in water generally decreases with increase in the degree of chlorination. Individual chlorobiphenyls vary in their water solubility from about 6 ppm for monochlorobiphenyl to as low as 0.007 ppm for octachlorobiphenyls. Solubilities of PCB's are also influenced by the environmental conditions. The aqueous phases in the environment generally contain dissolved organic substance, which probably increase the concentration of PCB's in the solution. Conversely, sorption of PCB's on soil and sediment surfaces in the aquatic environment help in decreasing their solution concentration.

PCB compounds have very low vapor pressure, which like their solubility in water, decrease with increased chlorination. In environmental samples where PCB's are sorbed on soil or sediment surfaces, the rate of vaporization of PCB's is greatly reduced. The vaporization rate of PCB's depend upon the sorption surface, thus the vaporization from soil and sediment surface is comparatively less than its vaporization from aqueous solution from where it is anomalously high because of low vapor pressure and high molecular weight. Commercial PCB's mixtures are light to dark yellow in colour. They do not crystallize, even at low temperatures, but turn into solid resins. PCB's are fire resistant with rather high flash points. They form vapours heavier than air, but these do not form any explosive mixtures with air. PCB compounds have very low electrical conductivity, high thermal conductivity and extremely high resistance to thermal breakdown. Because of these physical properties they are extensively used as cooling liquids in electrical equipments. PCB compounds are chemically stable under normal conditions, however when heated, vapours of other toxic compounds such as polychlorinated dibenzofurans (PCDFs) can be produced.

PCB's are practically insoluble in water, whereas they dissolve easily in hydrocarbons, fats and other organic compounds and they are readily absorbed by fatty tissues. All congeners of PCB's are lipophilic and have a very low water solubility that's the reason, they easily enter the food chain and accumulate in fatty tissues.

BACK HOME NEXT
Back to Content

Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

Production & Major Commercial uses of PCB's

The commercial production of PCB's began in 1930 and they have been used widely in electrical equipments. Between 1930 and 1977, the sole manufacturer of PCB's in United States – M/s Monsanto Company produced approx. 700,000 tonnes of PCB's, of which 75,000 tonnes were exported from the United States. By the end of 1980, the total world production of PCB's was in excess of 1 million tonnes and since then the production of PCB's has continued in several countries. Despite increasing withdrawal of the use and restrictions on the production of PCB's, very large amounts of these compounds continue to be used and existing in the environment, due to their unabated contribution in the past from their use or from the waste.

The major use of PCB's can be grouped in three major categories:

1. **Open Uses** e.g. use in paints, inks, plastics, paper coating, de-dusting agent, fire retardants, adhesives etc.
2. **Use in partially closed system -** heat exchangers, hydraulic system, vacuum pump, gas transmission, turbine, electrical capacitors and electrical transformers.
3. **Closed system use -** In closed system use the chances of PCB release to environment are comparatively less.

PCB's are valuable for industrial applications due to their chemical inertness, resistance to heat, low vapor pressure (particularly with the high chlorinated compounds), non-flammability and high dielectric constant. Throughout the 20th century, PCB's were used for many diverse purposes ranging from dielectric fluids to pesticide carriers. Their uses had been curtailed sharply in recent times. In a span of less than 20 years PCB's have moved from one of the most widely used chemicals to one of the most tightly controlled chemicals, because of their environmental implications in various other countries. The uses of PCB's for various applications is depicted in Fig. 2. PCB's are used for various applications viz. capacitors, transformers etc. The technical PCB's mixtures used in transformers are mostly highly chlorinated e.g. Aroclor 1254 and Aroclor 1260. Smaller volumes of PCB's have been often used as fire resistant liquid because of their high flash point. The valuable properties of PCB's as plasticizers has led to their use in furnishings, interior decoration, surface treatment for textiles, adhesive for water proof wall coatings, paints, putties and sealant. PCB's have also been used as plasticizers for plastic materials and in the formulation of printing inks. Although, most PCB's related activities have been banned or tightly restricted in western countries. PCB's still remain in industrial and commercial use in allowable concentration. In India, the uses of PCB for various purposes are not much clear and no definite information about these are readily available. However, it may be predicted that these compounds are extensively been used for various purposes in India.

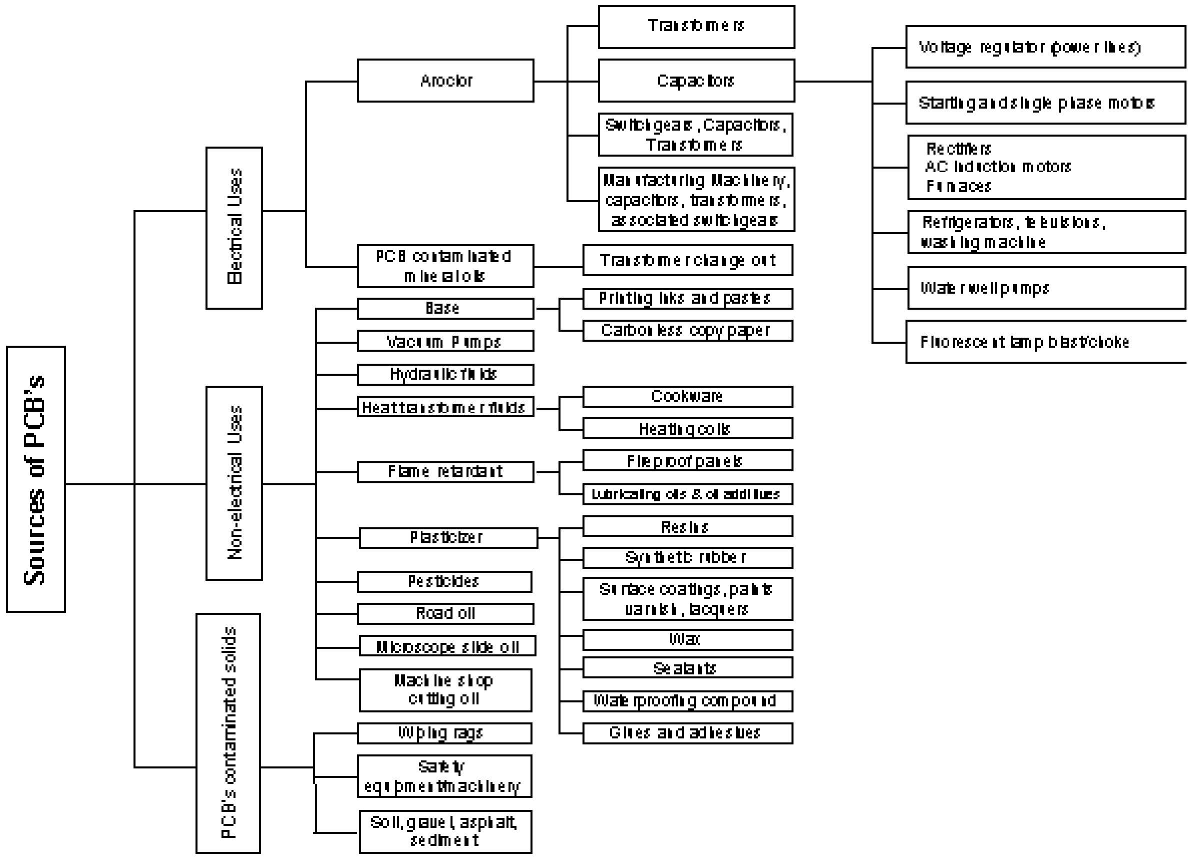

Fig. 2 Sources of PCB's in Environment

BACK HOME NEXT

Back to Content

Parivesh

A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

Eco-transportation of PCB's - Degradation & Elimination in Environment

The PCB's are among the most ubiquitous and persistent pollutants in global system. Because of their limited solubility in water, PCB's are usually found in only trace concentration in surface water, while these are available in appreciable concentration in body tissue of aquatic organisms from industrialized regions. The most common pathway of transportation of PCB's is through the air. The open burning or incomplete combustion of PCB's or waste containing PCB's, volatilization and transport of aerosol followed by atmospheric deposition are probably responsible for global dispersion of PCB's. The ability of PCB's to volatilize from landfills into the atmosphere (adsorption to aerosols with particle size of less than 0.05-20 µm) and resist degradation at low increasing temperatures, makes atmospheric transport the primary mode of distribution of PCB's. The half life of air borne PCB's particles depend greatly on the size of particles and the extent of atmospheric precipitation.

Duinker & Bouchertall (1989) analyzed filtered air, particulates and rain, in the city of Kiel, Federal Republic of Germany for fourteen different PCB congeners. Their study indicated that PCB congeners with a low degree of chlorination were dominant in filtered air, whereas, congeners with high degree of chlorination dominated in aerosols and rainfall. The vapor phase represented upto 99% of more volatile congeners. (The particulates were found to carry relatively more of the less volatile congeners). Particle scavenging was the dominant source of PCB's in rain water despite the small contribution of particulate PCB's to the overall atmospheric concentration of PCB's (only 1 or 2%). Precipitation scavenging of chlorinated hydrocarbons in the atmosphere is complex. Scavenging of particles by cloud droplets and by rain drops in and below clouds and the scavenging of the vapour phase occurs by rain. Thus, the chlorinated hydrocarbons are concentrated in precipitation rather than in the atmosphere, resulting in their high rainfall levels.

In water PCB's are adsorbed on sediments and other organic matter. Strong adsorption on sediment, especially in the case of higher chlorinated PCB's decreases the rate of volatilization. The transport of PCB's from sediment to water occurs because of desorption, bioturbation, gas convection and erosion. From the water, PCB's may be transported and enriched in the surface micro layer or transported to air. The PCB's deposited in sediments may directly be taken up from the sediment to the food chain by benthic organisms, while PCB's present in water tend to bio-accumulate in food chain through phytoplankton, zooplankton and other biota. On the basis of their water solubilities and n-octanol-water partition coefficients, the lower chlorinated PCB's congeners are sorbed less strongly than the higher chlorinated isomers. The low solubility and the strong adsorption of PCB's on soil particles limits leaching in soil. Lower chlorinated PCB's tend to leach more than highly chlorinated PCB's.

PCB's are highly resistant to degradation, once these are in the environment, these are sorbed onto the particles including sediments, suspended particulates and may bio-accumulate in organisms. Degradation of PCB's in the environment is dependent on the degree of chlorination of the biphenyl. The persistence of PCB's congeners increase as the degree of chlorination sets. In the atmosphere, the vapor phase reaction of PCB's with hydroxyl radicals (which are photochemically formed by sunlight) may be the dominant transformation process. In the aquatic environment, hydrolysis and oxidation do not significantly degrade PCB's. Photolysis appears to be the only viable abiotic degradation process of PCB's in the water.

It has been established that microorganisms degrade mono, di-, and tri-chlorinated biphenyls relatively rapidly and tetra-chlorobiphenyls slowly, whilst higher chlorinated biphenyls are resistant to biodegradation. Chlorine substitution positions on the biphenyl ring play an important role in determining the biodegradation rate. The PCB's containing chlorine atoms in the Para positions are preferentially biodegraded. Higher chlorinated congeners are bio-transformed anaerobically, by reductive dechlorination, to lower chlorinated PCB's, which may then be biodegradable by aerobic processes.

The first reaction step in the degradation of chlorobiphenyls in most cases is de-oxygenation, eventually leading to the formation of chloro-benzoates. The chlorine group in the ortho and meta positions offers steric hindrance to the degradation reaction.

Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

ENVIRONMENTAL ASSESSMENT OF PCB's

The Polychlorinated biphenyls (PCB's) are the class of pollutants, which impart considerable impact on the environment and human life due to their significant acute toxicity, high lipid activity and high bio-accumulation capacity. It has been estimated that substantial quantity of Aroclors had already been loaded in the environment globally, since the time PCB's were introduced and commercially used. The major amount of PCB's is released to the atmosphere during burning of paper, plastic or paint, and rest released to fresh and coastal water by leaks, disposal of industrial wastes, leaching and atmospheric fallout. Because of these reasons the PCB's have been recognized as the first industrial (non-pesticidal) product identified as ubiquitous environmental pollutants.

PCB's were detected first in the environment in the late 1960s and were reported globally as contaminants in almost every component of the ecosystem including air, water, soil, fish, wildlife, human blood etc. (Holdrinet et.al., 1977). The lipophilic properties of PCB's enhance bio-accumulation and biomagnification and thus various sources within the environment can lead to human exposure. The PCB's environmental concentrations in various environmental matrices are presented below:

Air

PCB concentrations in air varies from location to location, with the lower levels usually observed over the oceans and over non-industrialized regions. The average concentrations of Aroclors (calculated as Aroclor 1242 plus Aroclor 1254) in indoor air in work places in United States ranged from 44 to 240 ng/m3. Outdoor levels of PCB's upto 18 ng/m3 were observed. In the indoor air of homes in United States, the air samples from 14 areas (of which 9 were kitchens) were analyzed. The average concentrations of PCB's in the kitchens ranged from 150 to 500 ng/m3 and in other rooms from 39 to 170 ng/m3.

Water

Surface water may be contaminated with PCB's from direct discharge from point sources or alongwith atmospheric fall out. Because of adsorption on suspended particles, PCB's concentrations in heavily contaminated water may be several times greater than their solubility. It has been established that polluted rivers, lakes and estuaries have higher PCB values than non-polluted water.

Table 4 PCB's level in various Environmental Matrices

Environmental Matrices	Country	PCB's concentration range	Reference
Air	Canada	0.002-0.07 ng/m^3	Bidleman et.al. , 1978
	Germany	0.003-3.3 ng/m^3	DFG, 1988
	Japan	4-650 µg/m^3	Tatsukawa & Waterable, 1972
	Sweden	0.8-3.9 ng/m^3 (Industrial air borne Particulate Matter)	Ekstedt & Oden, 1974
	USA	1-50 ng/m^3	Panel on Hazardous Substances, 1972
Water	Germany	5-103 ng/l	Lorenz & Neumeier, 1983
	Sweden	0.1-0.3 ng/l	Ahnoff & Josefsson, 1974
	Netherlands	100-500 ng/l	Wegman & Greve, 1980
	USA	100-450 ng/l	Panel on Hazardous Substances, 1972

	India	0.19-1.93 ng/l	CPCB, 1999
Soil	Germany	0.02-0.08 ng/kg	Markard, 1988
	Japan	< 1 ng/kg	Fukada et.al. , 1973
	United Kingdom	0.2-12.2 µg/kg	Jones, 1989
		2.3-55 µg/kg	
	USA	0.6-1.7 ng/kg	Nimmo et.al. , 1971
	India	0.616-8.93 µg/kg	CPCB, 1999

ng/m^3 = Nanogram per cubic meter; ng/l = Nanogram per litre; µg/kg = Microgram per kilogram

Source *: Polychlorinated Biphenyls and Terphenyls; WHO Environmental Health Criteria, 140.*

PCB's in Water and Sediments of River Yamuna and Drains in Delhi

PCB's level in water and sediments have been assessed at five locations of Delhi stretch of River Yamuna and five major drains joining river Yamuna during May, 1999. The water and sediment samples collected from river and drains were pre-treated at CPCB Laboratory and forwarded to National Institute of Oceanography (NIO), Goa for Gas Chromatographic analysis of PCB's. The analysis results of total PCB's in river water, drain water and river and drain sediments are presented in Table 5 and the findings of the study are as below.

- Minimum and maximum levels of PCB's in water samples were found at old Yamuna Bridge and at Okhla i.e. 0.190 ng/l and 1.926 ng/l respectively, whereas in sediment samples minimum and maximum levels of PCB's were observed at Palwal (0.616 ng/g) and at Palla (8.927 ng/g) respectively.

Table 5 Concentration of Total PCB’s in water and sediment samples of Yamuna River and drains in Delhi

S. No.	Sampling locations	Total PCB’s in sediments (ng/g)	Total PCB’s in water (ng/l)
A. YAMUNA RIVER			
1.	River Yamuna at Palla	8.927	0.505
2.	River Yamuna at Old Yamuna Bridge	1.140	0.190
3.	River Yamuna at Nizamuddin Bridge	1.908	1.289
4.	River Yamuna at Okhla	0.641	1.926
5.	River Yamuna at Palwal	0.616	0.501
B. DRAINS			
1.	Najafgarh Drain	8.300	1.476
2.	Civil Mill Drain	281.397	4.738
3.	Power House Drain	0.282	6.545
4.	Sen Nursing Home Drain	1.361	0.288
5.	Shahdara Drain	5.010	1.540

- Among the major drains, the total PCB's in the drain water was recorded in the range 0.288 to 6.545 ng/l, whereas in sediments PCB's were in the range 0.282 to 281.397 ng/g. The highest concentration of PCB's in water and in sediment were detected in Power House Drain and Civil Mill Drain, respectively.
- The results indicate that after mixing of Civil Mill Drain and Power House Drain with river Yamuna, the PCB's levels in river water increased from 0.190 ng/l (at Old Yamuna Bridge) to 1.926 ng/l (Okhla) indicating that PCB's are contributed by the drains alongwith the wastewater. The level of PCB's again decreased to 0.501 ng/l down stream to Okhla, may be due to dilution or PCB's removal through bio-accumulation.
- The US Environment Protection Agency (USEPA) Guidelines has recommended the criteria limit of 14.0 ng/l in its National Recommended Water Quality Criteria for Non-priority pollutants in fresh water (Ref: Federal Register, Vol. 63 No. 237, 1988). The analysis results indicate that PCB's levels in water at all the locations of river Yamuna as well as in drains are well within the limit.

Soil

Soil may become contaminated with PCB's from direct discharge from point sources. The presence and behavior of PCB's in the soil depend on congener specific characteristics and on a number of soil parameters. Sorption and condensation processes in the soil plays major role in the removal of PCB's. PCB's accumulate in the sediments of rivers and lakes and this accumulation indirectly reflect the contamination of water. An important, though localized, source of PCB's contamination of soil can be the use of sewage sludge as a fertilizer in agriculture. PCB's levels varying from 0.1 to 765 ng/kg (dry weight) have been reported in sewage sludge from different countries, the usual range being 0.1 to 9.0 mg/kg (WHO/EURO, 1987).

PCB's Levels in Human Food

The presence of specified isomers of PCB congeners in Canada in fatty foods of the Canadian diet had been studied by Mes et.al. (1989) in which total of 93 food composites from the cities of Ottawa and Halifax were analyzed for 34 PCB's isomers. The PCB's isomers 118, 138, 153 and 180 were found in all dairy products, except skimmed milk while, cheese and butter contained the highest levels of PCB residues. The residue level of PCB isomer 118 (2,3',4,4',5-pentachlorobiphenyl) in butter was the highest while 0.7 µg/kg of all PCB isomers were found in dairy products. Almost all meat, fish and poultry contained PCB isomers 183 and 187. Occasionally, isomers 49, 87, 185 and 189 were also present.

Fresh water fish contained most PCB isomers (28 out of 34 selected PCB isomers), at levels considerably higher than those in any other meat, fish or poultry samples. The level of isomer 110 in fresh water fish was 3.05 µg/kg.

The PCB levels obtained in the food in an extensive study at United States during 1972 by the US Food and Drug Administration are presented in Table 6.

Table 6 PCB's Levels in Food in United States of America

S.No.	Food items	% Sample with positive presence of PCB's (0.1 µg/kg)	Levels in the food samples (mg/kg)	
			Min	Max
1.	Cheese	6	0.25	1.0
2.	Milk	7	2.3	27.8
3.	Eggs	29	0.55	3.7
4.	Fish	54	1.87	35.3

BACK HOME NEXT

Back to Content

Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

BIO-ACCUMULATION AND BIO-TRANSFORMATION OF PCB's

PCB's are persistent and stable compound and they do not degrade rapidly and are passed up to aquatic food chain in increasing level. This phenomenon is known as bioaccumulation. PCB's accumulate in tissues of almost all organisms, because of their high lipid solubility and slow rate of metabolism and elimination. They accumulate preferentially in fat-rich tissues

Uptake by micro-organism of both pure chlorinated biphenyl isomers and commercial PCB mixtures is rapid, and high bio-concentration factors are achieved. According to some studies PCB congeners with higher levels of chlorination are taken up preferentially, in the majority of studies, all PCB's appear to be taken up equally. Uptake by micro organism is true absorption; adsorption onto the surface of the organisms represent little of the uptake. Since, resistant forms, of micro-organisms take up less PCB's than sensitive forms and dead cells accumulate more PCB's than live cells, there is some capacity to exclude the compounds.

Uptake of PCB's into plants from soil is positively correlated with the soil concentration of the PCB's. The accumulation capacities of roots are more than the stems and foliage. Lower chlorinated congeners of the PCB's are taken up more by the plants, probably because of their greater mobility in the soil.

The PCB's uptake by plants is influenced by following factors:

- The PCB's concentration in the soil.
- CPCB's uptake between plant species are different, some species absorb more PCB's than others.
- Most of the PCB's in roots may, in fact, be adsorbed on the surface and not actually taken up.
- There is a general trend of increasing PCB content with decreasing chlorination for pure PCB congeners.
- The amount of chlorination seems to have an effect on the mobility of PCB's within plant parts. The lower chlorinated PCB's have been reported to be more mobile in soils than highly chlorinated PCB's.

Fish of all life stages absorbs PCB's readily from water. PCB's with greater chlorination are more readily taken up and retained. PCB's body burden tends to increase with age of the fish and levels are higher in fish with greater lipid content. Depending on the species, habitat, and behavior, PCB's can be taken up from water, sediment or food to different degree.

In Birds, the PCB's are taken up from contaminated food or water and concentrated in the fatty tissues. PCB's of higher chlorination levels are accumulated to a greater extent. Egg-laying females can transfer substantial amounts of PCB's from body tissues to the eggs. Redistribution of PCB's residue occurs on starvation (starvation is significant during the migration of birds in the wild). Most critically, PCB residues in the brain increase during starvation and this may kill the birds without further intake of PCB's.

Yusho Accident, 1968 - Japan

In June, 1968 patients appeared at the Dermatology clinic of Kyusthu University Hospital, Fukuoka, Japan suffering from chloracne. After few clinical, chemical and epidemiological investigations, it was found that the disease originated from the consumption of a batch of rice oil supplied in February, 1968; the disease was called Yusho (rice oil disease). This rice oil was found contaminated with Kanechlor 400, a 48% chlorinated biphenyl, at 2000-3000 mg/kg, which entered the oil through a leak in the heat exchanger. Chlorinated dibenzofurans at 5 mg/kg were found in three samples of toxic rice oil that contained PCB levels of about 1000 mg/kg (Nagayama et.al., 1976).

The earliest symptoms of PCB's exposure were enlargement and hyper-secretion of the

Meibonian glands of the eyes, swelling of the eyelids and pigmentation of the nails and mucous membranes, occasionally associated with fatigue, nausea and vomiting. This was followed by hyperkeratosis and darkening of the skin with follicular enlargement and acneform eruptions. These skin changes were most often seen on the neck and upper chest, but in severe cases, extended to the whole body.

Biopsy skin samples showed hyperkeratos i.e. dilation of the follicles, and an accumulation of melanin in the basal cells of the epidermis; melanin granules have also been observed in biopsy samples of the conjunctiva, oedema of the arms and legs was also observed in some patients. The majority of the patients were found to have respiratory symptoms and suffered from chronic bronchitis like disturbance, that persisted for several years.

Yusho patients did not appear to suffer from central nervous effects, but some complained of numbness of the arms and legs. Nuco-cutaneous signs had decreased year-by-year, but neurological signs, respiratory signs and symptoms and various complaints, as general fatigue, anorexia, abdominal pain and headache, had become more prominent among the patients.

Yusho Accident, 1968 - Japan

A similar incident to Yusho accident occurred in Taiwan in 1979, and by the end of 1980, the number of affected persons were found 1843. The incident has been referred to as Yu-Cheng (Chang et.al., 1980a, b; Chen et.al., 1980). The accident had occurred due to the consumption of rice bran oil contaminated with PCBs that was used as a heat transfer medium in the manufacture of the oil. PCB intake was estimated to be 0.7-1.84 g and blood PCB levels ranged from 3 to 1156 µg/litre. The formation and hypersecretion of the meibonian glands occurred in patients, whose blood PCBs concentration was above 40 µg/litre.

The common symptoms noticed were heavy pigmentation of conjunctiva, abnormal cystic acneiform eruptions and follicular accentuation, skin and nail pigmentation, swelling of the eyelids and increased discharge from the eyes, headache, nausea, and numbness of the limbs. The major blood disorders were decreased hemoglobin concentration, erythrocyte conc., gamma-immunoglobin and increased white blood cell counts.

BACK HOME NEXT

Back to Content

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

TOXICOLOGICAL EFFECTS OF PCB's ON HUMAN BEINGS

PCB's can reach to human being through bio-transfer route and may accumulate in fatty tissues. PCB's are inhaled in small amounts through the air or ingested through food. People are primarily exposed to PCB's by consuming fish from contaminated water, but they can also be exposed through other foods.

Since, PCB's are lipophilic, they are preferentially stored in adipose tissue. They are also present to a smaller extent in serum, organs and tissues and human milk. The concentrations of PCB's in the different organs depend on the lipid content of such organs, with the exception of the brain, where the concentration is lower. PCB's to a certain extent pass through the placenta. They are primarily excreted through bile and milk.

Yusho Accident, 1968 and Yu-Cheng Accidents 1980 are two unfortunate examples of effects of short and long term exposure of PCB's to humans.

Within few hours of acute exposure to PCB's, skin rashes may occur. Exposure through ingestion is possible in the working environment through direct ingestion alongwith hand and contaminated food. Skin exposure is important in the case of long term exposure, even though the ambient concentration may be low.

Table 8 PCB Congeners Important from Human Health viewpoint

	BZ Number	IUPAC Nomenclature
A.	**Known to cause direct toxicity**	
	PCB-BZ 77	3,3',4,4'-Tetrachlorobiphenyl
	PCB-BZ 126	3,3',4,4',5-Pentachlorobiphenyl
	PCB-BZ 169	3,3',4,4',5,5'-Hexachlorobiphenyl
B.	**Stimulate the production of bio-activate enzyme**	
	PCB-BZ 105	2,3,3',4,4',-Pentachlorobiphenyl
	PCB-BZ 118	2,3',4,4',5-Pentachlorobiphenyl
	PCB-BZ 128	2,2',3,3',4,4'-Hexachlorobiphenyl
	PCB-BZ 138	2,2',3,4,4',5'-Hexachlorobiphenyl
	PCB-BZ 156	2,3,3',4,4',5-Hexachlorobiphenyl
	PCB-BZ 170	2,2',3,3',4,4',5-Heptachlorobiphenyl
C.	**Frequently found at high concentration levels in environmental samples or animal tissue**	
	PCB-BZ 18	2,2',5-Trichlorobiphenyl
	PCB-BZ 44	2,2',3,5'-Tetrachlorobiphenyl
	PCB-BZ 49	2,2',4,5'-Tetrachlorobiphenyl
	PCB-BZ 52	2,2',5,5',-Tetrachlorobiphenyl
	PCB-BZ 70	2,3',4',5-Tetrachlorobiphenyl
	PCB-BZ 74	2,4,4',5-Tetrachlorobiphenyl
	PCB-BZ 151	2,2',3,5,5',6-Hexachlorobiphenyl
	PCB-BZ 177	2,2',3,3',4',5,6-Heptachlorobiphenyl
	PCB-BZ 187	2,2',3,4',5,5',6-Heptachlorobiphenyl

	PCB-BZ 207	2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl
D.	**Mixed type inducers found at low concentration in tissues**	
	PCB-BZ 37	3,4,4'-Trichlorobiphenyl
	PCB-BZ 81	3,4,4',5-Tetrachlorobiphenyl
	PCB-BZ 114	2,3,4,4',5-Pentachlorobiphenyl
	PCB-BZ 119	2,3',4,4',6-Pentachlorobiphenyl
	PCB-BZ 123	2',3,4,4',5-Pentachlorobiphenyl
	PCB-BZ 157	2,3,3',4,4',5'-Hexachlorobiphenyl
	PCB-BZ 158	2,3,3',4,4',6-Hexachlorobiphenyl
	PCB-BZ 167	2,3',4,4',5,5'-Hexachlorobiphenyl
	PCB-BZ 168	2,3',4,4',5',6-Hexachlorobiphenyl
	PCB-BZ 189	2,3,3',4,4',5,5'-Heptachlorobiphenyl

BACK HOME NEXT

Back to Content

Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

SHIP BREAKING ACTIVITIES - SOURCE OF TOXIC/HAZARDOUS WASTE INCLUDING PCB's IN INDIA

Ship breaking activities involve breaking of old obsolete/damaged ships and recovery of construction material (mostly steel and other items) for recycling and reuse. Ship breaking had been regular commercial activity in some industrially advanced countries like UK, USA, Germany during first half of last century, but after 1960 the activity shifted from industrialized countries to other areas in Asia and Far East. Among Asian Countries, actively involved in Ship breaking activities are India, Bangladesh, Taiwan, China, South Korea, Japan and Pakistan. India has emerged as leading nation involved in Ship breaking activities because of demand of re-rollable and melting scrap steel and other items within the country.

Till 1960, ship breaking involves mainly dismantling of small-disused barges and coastal wretches but during seventies, the ship breaking activity registered commendable growth and later by the year 1979 it was recognized as full fledged small scale industry. The activity, which was confined to Mumbai and Kolkata, spread primarily on the western coast and other parts of the country. The major centres for ship breaking activities in the country are:

S. No.	State	Ship breaking Activity locations
1.	Andhra Pradesh	Vishakhapatnam
2.	Gujarat	Alang
		Sachna
3.	Karnataka	Tadri
		Mangalore
		Malpe
4.	Kerala	Baypore
		Cochin
		Azhical
5.	Maharashtra	Mumbai
6.	Tamilnadu	Tuticorin
7.	West Bengal	Kolkata

Ship Breaking Process

Ship breaking activity is undertaken by private entrepreneurs and it is a labour intensive process, in which discarded ships are beached during high tide and dragged towards the shore by shore based winches. The material, which is physically removed from the discarded ships before its further breaking include:

- Removal of Ballast water, fuel oil, lubricants, electrical items, loose cables, fire fighting equipments, ladders, window panel, frames etc.
- Removal of moveable gear, electrical navigation equipments, nylon and steel ropes, shackles, pulley blocks, tarpaulin, paints and lubricant tins, machinery, spares etc.
- Removal of auxiliary equipment of prime mover machinery like diesel generator sets, boilers, air compressors, pumps, valves etc.
- Dismantling of main engine in parts - head, main block, piston, crankshaft and bore. Removal of propeller, its shaft etc.

After removal of material physically from the ship, the steel structure of vessel is cut vertically by Oxygen-LPG into large blocks. The cut blocks are dropped on the beach/ground on either side of vessel and large dismantled pieces are pulled up to onshore yard, where they are further cut up into small pieces for sorting and selling as steel scrap and rerollable steel for recycling to iron and steel industry.

Environmental Impact from Ship Breaking Activities

The shipping activities usually produce different organic and inorganic material, which pollute the area, if their removal is not controlled during dismantling. The potential source of toxic and hazardous pollutants during the ship breaking activity are:

- Fuel oil and Lubricants
- Oil sludge in oil tankers and oil/bulk ore carrier
- Solid waste viz. hydrated/solidified cement
- Heavy metals like Tin, Lead and chemical constituents of paints and coatings.
- Remnants of toxic chemicals in cargo compartment of chemical carriers.
- Bilge and ballast water.

Apart from the above, during breaking of ships several other pollutants are generated, which have considerable environment impact and hazards. Some of these are:

- Inflammable gases from cargo tank of Oil/LPG/Naphtha, sometimes ammonia from chilling system of cold stores
- Compressed carbon dioxide, freons etc.
- Paint chips, which are the source of several heavy metals viz. Pb, Cr, Cu and Organic compounds like PCB's.
- Solid waste - small scrap iron, metallic pieces, glass wool, rubber pipes, gaskets, PVC sheet and pipes, corks, wooden pieces, asbestos etc.
- Oily material from cleaning of cargo hold, iron scales, rust during cutting and cleaning of scrap.
- Cementing material, tiles, iron scales are dumped to low lying areas and at beaches contaminating land surface
- PCB's laden oil, toxic material laden paints etc.

Preventive Actions Envisaged

- Wastes containing PCB's and other toxic material generated from ship breaking activities should be reprocessed and reused as raw material.
- PCB's contaminated transformers, PCB's laden articles, rags, soils and other debris contaminated with PCB's have to be incinerated at very high temperature.
- Discarded items from ship suspected to contain PCB's should be stored in such confined area having impervious flooring to ensure containment of PCB's.
- The presence of radioactive material on discarded vessels should be ascertained well in advance. The ships containing radioactive material should not be permitted to be broken.
- Ship breaking activities site should be maintained properly to avoid land/water contamination. House keeping measures should be improved.
- Bilge water and Ballast water should be appropriately treated before its final disposal.

BACK HOME NEXT

Back to Content

Parivesh
A News Letter from ENVIS Centre - Central Pollution Control Board

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

HAZARDOUS PCB's WASTE - HANDLING, TREATMENT & DISPOSAL

The PCB's waste requiring disposal mainly consist of:

- Waste arising during the manufacturer / use of PCB's - both solids and liquids.
- Dielectric fluid removed from transformers because of degradation and contamination
- Dielectric fluid in scrapped transformers
- Dielectric of scrapped capacitors in manufacture and in redundant equipment
- PCB's contaminated material e.g. scrap capacitors, windings, absorbent material used in cleaning equipment or spills - Imported Waste.

PCB's Waste from its major uses

(a) Transformers

The PCB's have been used in transformers since 1940 because of their high boiling points, stability, non-flammability and dielectric characteristics. The adequate disposal of transformers dielectric fluid should be mandatory in order to escape from environmental consequences. PCB's filled transformers are principally used, where the consequence of fire from ignition of the dielectric due to arcing or from an external source would be serious e.g. in ships, basement of buildings and mines. However, the dense fumes, which are evolved when PCB's are subjected to high temperature makes them unacceptable in some situations. The rejected dielectric and scraped transformer contribute the PCB's waste to the environment.

(b) Capacitors

The capacitors are used to smooth out the large load fluctuations on industrial power supply systems. The lower chlorinated PCB's are used in large capacitors. Even in small electrical gadgets, the small PCB's filled capacitors are fitted particularly in fractional horse power motors used in domestic and light industrial electrical equipment. Typically these contain lower chlorinated PCB's mainly absorbed on the windings. The PCB's waste in these application arises, when the equipment is scrapped, capacitors replaced and during manufacture of capacitors. In present time, there have been considerable reduction of PCB's used in the capacitors.

PCB's Waste Treatment and Disposal Methods Adopted in Various Countries

The method of treatment and disposal of PCB's waste as adopted in various countries involve mainly following methods.

A. Incineration
Most of the PCB waste generated are destroyed by controlled incineration in the units fitted with wet gas scrubbing systems capable of achieving sustained temperature of 11000C. The waste disposal by this method is used particularly for following processes:

- Liquid waste from manufacturing process and from transformers and large capacitors
- Solid waste from manufacturing process usually cast in drums.
- Miscellaneous solid waste including waste from manufacture of small capacitors, contaminated rags, saw dust, fuller's earth etc. at manufacturing and handling plants.

B. Heat Treatment
Certain PCB's wastes are subjected to varying degree of heat treatment in some countries. These are principally

associated with scrap, small capacitors, which are recovered from domestic waste. The capacitors shell of aluminium are separated but the separation process is not completely effective and some PCB's associated with it finds its way into the scrap, which is destroyed at higher temperature during scrap melting. During the heat treatment process some PCB's escape to the atmosphere, though in diluted form.

C. Landfill
In several countries, small capacitors scrap arising from use in starter circuits, fractional horsepower electric motor application is disposed to landfill or in redundant appliances. One of the main routes is via the domestic refuse, which is taken for landfill, and the item is buried at the bottom of layer of refuse, if not recycled. Small quantities of contaminated rags, paper, sawdust etc. arising at manufacturing and handling plant also reach to the landfill.

D. Recovery
The PCB's waste principally from transformer applications and also from large capacitors is recovered by clarification and vacuum distillation process. In large capacitors, the excess fluid is drained off for recovery and incineration.

E. Other disposal method
The PCB's waste in some countries are stored isolatedly, pending the availability of acceptable disposal method and accumulated backlog is still largely dealt with incineration.

Recommendations for Proper Handling and Disposal of PCB's Waste

a. Labelling of Products and Wastes

Modern Electric transformers and large capacitors containing PCB's should be identified with labels, informing buyers the need for adequate disposal. The manufacturer should undertake retrospective labelling, wherever possible. The strict maintenance procedure for PCB's filled units are required in comparison to units filled with hydrocarbon oils.

b. Storage and Containment

The bulk liquid PCB's and waste liquid PCB's must be adequately sealed and well labelled and stored in heavy duty containers, but not in standard drums. In case of highly chlorinated type of PCB's used in transformers, appropriate labelling should be used by the manufacturers. The PCB's for reclamation from PCB's based material should be stored in sealed containers to avoid contamination of external environment

c. Handling

Appropriate housekeeping is mandatory, when PCB's are utilized for any product manufacture. The transfer of liquid PCB's should have to be appropriately conducted to ensure, that it should not be a residual source of pollution.

Where large quantities of PCB's are still used, the bunds, dump tanks should be provided to prevent PCB's passing into the drains, if the dielectric fluid is mishandled. Strict precautions should be taken to ensure that PCB's do not enter into sewerage system or watercourse particularly from old disused transformer dump yard or storage place.

BACK HOME NEXT

Back to Content

POLYCHLORINATED BIPHENYLS (PCB's) - Environmental Implications

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BACK HOME

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