RISK ASSESSMENT OF POLYCHLORINATED BIPHENYLS (PCBs) IN INDOOR AIR

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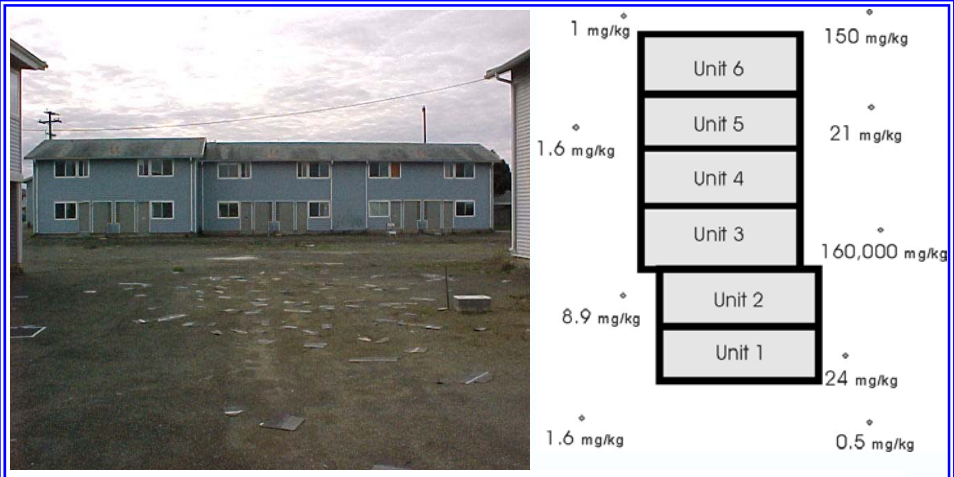
ABSTRACT

In the 1970's, residences were built on a site where recent investigation found PCBs (Aroclor 1260) in soil at concentrations up to 160,000 mg/kg. Contaminated soil was removed to a target level of 1 mg/kg, but soil under the residences was not removed or sampled. Though PCBs are relatively non-volatile, they are complex mixtures and there is a potential for transport of some constituents from soil through the foundation into indoor air. A screening analysis (U.S. EPA's Johnson and Ettinger model for subsurface vapor intrusion based on a saturation soil concentration of 139 mg/kg) estimated 2000 ng/m^3 in indoor air, corresponding to a potential cancer risk of 6E-4. Seven indoor air samples were collected, in four sampling events over 13 months. Congener-specific analysis using GC/SIM-MS measured total PCBs in indoor air ranging from 96 to 234 ng/m^3. The congeners measured in indoor air were mostly monochlorinated. Cancer risk estimates for the detected concentrations range from 3E-5 to 7E-5.

CONTAMINATED RESIDENTIAL AREA

Historical aerial photographs showed that part of a residential area, constructed in the early 1970s, was the site of a former storage yard. Environmental sampling found widespread polychlorinated biphenyls (PCB) contamination with concentrations up to 160,000 mg/kg in soil. Contaminated soil was removed up to the foundations of the nearest buildings. The levels and distribution of the contamination suggested the possibility that high levels of PCBs might underlie the slab foundation of at least one of the multi-unit buildings.



Subject Building and Aroclor 1260 Concentrations in Soil

Air Sampling Equipment

INDOOR AIR MODELS

Three modeling ex ises were: (1) Preliminary modeling of vapor intrusion into indoor air used the U.S. EPA (1998) Johnson and Ettinger screening model. Soil was assumed to be sandy and contaminated with Aroclor 1260 immediately below the slab. The saturation level (139 mg/kg) was assumed, rather than the highest soil concentration (160,000 mg/kg). This predicted indoor air concentrations of 2000 ng/m^3. (2) Application of the U.S. EPA NAPL-SCREEN model evaluated 160,000 mg/kg as a nonaqueous phase liquid and predicted indoor air concentrations of 2000 ng/m^3. (3) CalTOX is a screening model developed by the CA Dept. of Toxic Substances Control to evaluate direct and indirect exposure to soil contaminants through multiple exposure pathways. Using default parameter values describing California conditions, CalTOX predicted that 160,000 mg/kg in soil would produce an indoor air concentration of 14 ng/m^3.

INDOOR AIR MEASUREMENTS

Before sampling, each unit was opened for 24 hours and then closed for at least 72 hours. Indoor air samples were collected with a polyurethane foam (PUF) cartridge and a pump, using a low volume technique over eight hours. Samples were analyzed by U.S. EPA Method 1668. Indoor air was sampled in all six units of the building near the greatest PCB contamination in soil. The highest indoor air concentration was in Unit 3, adjacent to the highest soil concentration. Lower indoor air concentrations were measured in Units 1, 2, and 4, corresponding to lower soil concentrations. Units 5 and 6 lacked measurable PCB concentrations in indoor air. Four additional rounds of air sampling confirmed the presence of PCBs in Unit 3 air. The data from one round are excluded here because of evidence of contaminated equipment.

Detected Congener Concentrations in Indoor Air (ng/m^3)

Unit	Date	Mono PCB1	Mono PCB3	Di PCB8	Tri PCB18	Tri PCB28	Hexa PCB149	Hexa PCB151	Hexa PCB153	Hepta PCB187
1	10/7/00	6	*	*	*	*	*	*	*	*
2	10/7/00	*	0.8	*	*	*	*	*	*	*
3	10/7/00	158	57	0.5	0.5	*	1.1	0.6	0.6	*
3	1/8/01	82	34	*	*	*	0.9	0.6	0.6	*
3**	1/8/01	75	31	*	*	*	0.8	0.5	0.5	*
3	11/27/01	135	54	0.6	0.6	*	1.0	0.6	0.7	0.4
3**	11/27/01	124	49	0.6	0.6	0.4	1.1	0.6	0.7	0.5
3	11/28/01	63	27	*	*	*	0.7	*	0.4	*
3**	11/28/01	63	26	*	*	*	0.7	*	0.4	*
4	10/7/00	9.5	*	*	*	*	*	*	*	*
5	10/7/00	*	*	*	*	*	*	*	*	*
6	10/7/00	*	*	*	*	*	*	*	*	*

* = *not detected (detection limit of 0.5 ng/m3)*

** = *duplicate sample*

Note - not all detected congeners are shown.

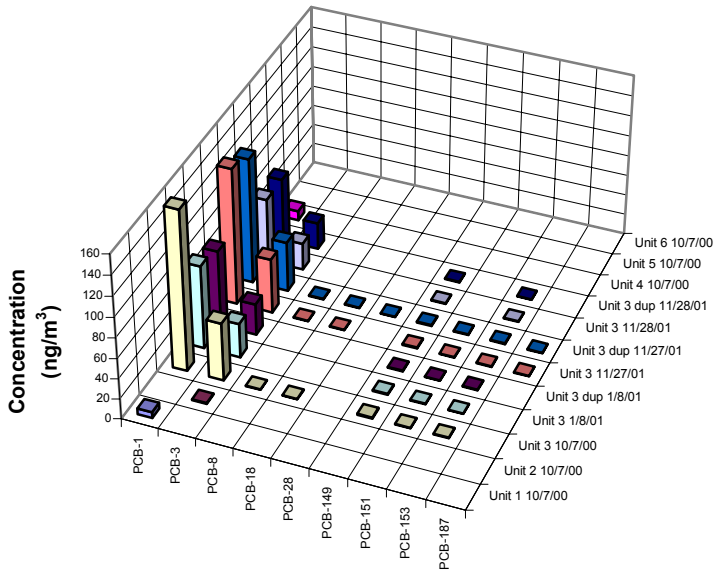
Conclusions:

(1) Indoor air contamination is strongly correlated with levels of soil contamination.

(2) The highest concentrations and greatest diversity are in Unit 3.

(3) The preponderance of indoor air congeners are monochlorinated.

Detected Concentrations of PCB Congeners in Indoor Air (ng/m^3)



CONGENER ANALYSIS

The predominant congeners in Unit 3 air were PCB-1 (2-chlorobiphenyl) and PCB-3 (4-chlorobiphenyl). Other isomers at much lower concentrations in Unit 3 air were di-, tri-, penta-, hexa-, and heptachlorobiphenyls. Following the air sampling, soil samples were collected at 5, 7 and 9 feet below ground surface for congener analysis. Low PCB concentrations were found, with different congener patterns at each depth, none of which resembled Aroclor 1260. The proportions of low molecular weight congeners increased substantially with depth. These soil samples may not be representative of the contaminated soil which was removed or the soil under the buildings.

Congener Contributions (Percent of Total) in Different Mixtures

	Chlorine Positions	Indoor Air	Soil Depth			Aroclor 1260[a] (Most Abundant)	Vapor Loss[b] (10 Highest)
			5 ft	7 ft	9 ft		
PCB-1	2	69 to 100	2.4	17.9	38.3	--	--
PCB-3	4	26 to 100	*	*	*	--	--
PCB-8	2,4'	0.2 to 0.3	*	*	7.9	--	--
PCB-18	2,2',5	0.2 to 0.4	6.9	*	*	--	--
PCB-28	2,4,4'	0.3	*	*	*	--	--
PCB-66	2,3',4,4'	*	*	*	*	--	9.3
PCB-101	2,2',4,5,5'	*	1.7	*	*	3.1	10.0
PCB-129	2,2',3,3',4,5	*	*	*	*	--	5.2
PCB-132	2,2',3,3',4,6'	*	*	*	*	2.9	9.2
PCB-138	2,2',3,4,4',5'	*	1.8	*	*	6.5	8.0
PCB-149	2,2',3,4',5',6	0.5 to 0.8	1.9	*	*	8.8	14.6
PCB-151	2,2',3,5,5',6	0.3 to 0.5	*	*	*	3.0	5.2
PCB-153	2,2',4,4',5,5'	0.3 to 0.5	1.8	*	*	9.4	9.2
PCB-170	2,2',3,3',4,4',5	*	0.4	2.1	*	4.1	--
PCB-174	2,2',3,3',4,5,6'	*	*	*	*	5.0	--
PCB-180	2,2',3,4,4',5,5'	*	0.9	4.5	1.1	11.4	--
PCB-182	2,2',3,4,4',5,6'	*	*	*	*	--	3.5
PCB-187	2,2',3,4',5,5',6	0.2 to 0.3	*	*	*	5.4	3.5

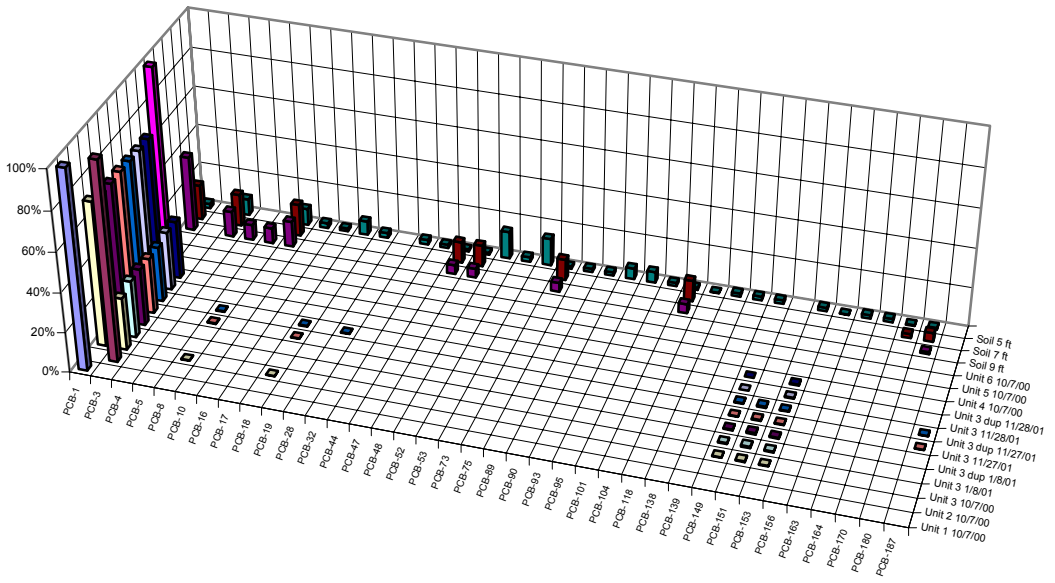
[a] *As reported by EPA, 2001*

[b] *As reported by Chiarenzelli et al., 1997*

-- *Not among 10 largest contributions*

* *Not detected (0.04 to 0.4% for 5-ft sample, 0.07 to 1% in 7-ft sample, 0.05 to 5% in 9-ft sample)*

Congener Contributions (Percent of Total) in Indoor Air Samples



DISCUSSION

Indoor air sampling and analysis confirmed the modeling predictions that the soil concentrations of PCBs are sufficient to result in vapor intrusion. The potential excess cancer risk associated with the PCB concentrations in Unit 3 air ranges from 3E-5 to 7E-5. These estimates were derived from the U.S. EPA Region 9 Preliminary Remediation Goal for Aroclor 1260, based on cancer risk for residential air. However, the congener mixtures found in indoor air are very different from the mixtures tested for toxicity, limiting the applicability of bioassay results and complicating the selection of appropriate toxicity values.

The repeatable finding of PCB-1 and PCB-3 as the primary indoor air components is consistent with the expectation that the more volatile (lower molecular weight) congeners would be enriched in vapors and with the elevated monochlorobiphenyl levels observed in soil. Further, penta- and hexachlorobiphenyls with the highest concentrations in the indoor air samples are among the most abundant congeners in Aroclor 1260.

Our observations are also consistent with measurements of PCB vapor losses from wet sand (Chiarenzelli et al., 1997). The PCB congeners observed in soil suggest the possibility of reductive dechlorination, which would alter the composition of the original Aroclor 1260 mixture and enrich the source of monochlorobiphenyl vapors.

CONCLUSIONS

Vapor intrusion modeling is useful to indicate the potential for meaningful concentrations of PCBs in indoor air.

PCB contamination in soil represents a potential source of inhalation exposure in indoor air.

Environmental fate processes, notably in situ reductive dechlorination, may substantially affect the potential for exposure to PCB vapors in indoor air.

Selection of appropriate toxicity criteria for the measured PCB vapors is complicated by the congener mixtures detected.

REFERENCES

Chiarenzelli, JR, RJ Scrudato, ML Wunderlich, 1997. Volatile Loss of PCB Aroclors from Subaqueous Sand. Environ. Sci. Technol. 31:597-602.

U.S. EPA, 1998. User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion Into Buildings. Office of Emergency and Remedial Response. September 1998.

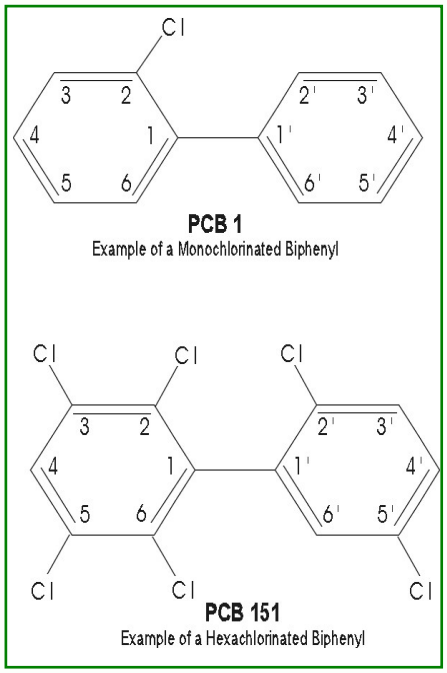
U.S. EPA, 2001. PCB Congener Composition of Aroclor Mixtures.

CHEMISTRY AND USES OF PCBS

Polychlorinated biphenyls (PCBs) are biphenyl molecules linked by a carbon-carbon bond at the 1-1' position. The other 10 positions on the phenyl rings are substituted with 1-10 chlorine atoms, resulting in 10 isomers (mono-, di-, tri-, etc.). There are 209 individual PCB congeners. Aroclors are industrial mixtures of PCBs, differing in level of chlorine substitution. Aroclor 1260 contains 60 percent chlorine by weight.

PCB manufacture began about 1930. Because of their heat stability, low reactivity and lubricating properties, PCBs had a variety of industrial uses (electrical transformers and capacitors, hydraulic fluid, paints, inks, adhesives, paper products, etc.).

PCBs were banned in the U.S. in 1977, because of their bioaccumulation, persistence in the environment, and toxicity. Current contamination at many hazardous waste sites demonstrates the persistence of PCBs.



PCB 1
Example of a Monochlorinated Biphenyl

PCB 151
Example of a Hexachlorinated Biphenyl

TOXICITY OF PCBs

Both U.S. EPA and the International Agency for Research on Cancer classify PCBs as probable human carcinogens. Feeding studies in rodents provide strong evidence that PCBs cause cancer. Studies of workers exposed to PCBs are suggestive of carcinogenicity. PCBs also exhibit noncarcinogenic toxicity (dermal, endocrine, hepatic, neurodevelopmental, possibly immune system) in animals and humans.

U.S. EPA provides different cancer risk slope factors for PCBs along with guidance on the types of exposures to which each applies. The upper bound slope factors are 0.07, 0.4 and 2.0 $[mg/(kg \times day)]^{-1}$, based on the results of bioassays on four Aroclors (1260, 1254, 1242, and 1016).

U.S. EPA Region 9 has published a Preliminary Remediation Goal for PCBs in residential air of 3.4 ng/m^3, based on a 1×10^{-6} target cancer risk and the highest-potency Aroclor mixture.