HUMAN HEALTH RISK ASSESSMENT FOR EXPOSURE TO POLYCHLORINATED BIPHENYLS IN CONTAMINATED BUILDINGS

Wong-Yim, Patty [1,2]; Wade, Michael [2]; Davis, Brian [2]; DiBiasio, Karen [2]; Taras, Tracy [2]

Cal/EPA: [1] Office of Environmental Health Hazard Assessment, and [2] Department of Toxic Substances Control

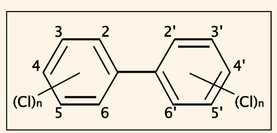
ABSTRACT

It is not uncommon to find polychlorinated biphenyls (PCBs) contamination inside industrial buildings, because of extensive use in the past, especially in transformers. Limited guidance is available for conducting human health risk assessment (HHRA) for exposure to contaminants on building surfaces rather than environmental media. By adopting exposure parameters from the few available scientific reports, this paper presents HHRAs performed on two buildings at a facility in California. Previous use and spills of PCBs were reported in Buildings A and B, resulting in surface contamination on flooring materials (concrete, wood, and asphalt) inside the buildings. Concrete chips, dust, wall wipes, and indoor air were sampled inside these buildings during site investigation. Maximum PCB levels of 69 ng/m^3 indoor air and 0.7 mg/kg in concrete chips were used in the HHRA for Building A. Since the proposed future use of Building A is residential, incidental ingestion and direct dermal contact with the contaminated floor were considered incomplete exposure pathways. The residential cancer risk estimate and non-cancer hazard index (HI) from inhalation of indoor air are 2E-5 and 0.9. The industrial worker cancer risk estimate and non-cancer HI from inhalation of indoor air are 1E-5 and 0.7. For the industrial Building B, maximum PCB levels were 19 ng/m^3 in indoor air and 105 mg/kg in concrete chips. Human exposure via inhalation of indoor air, direct dermal contact, and incidental ingestion of dust on the floor were evaluated. The cancer risk estimate and non-cancer HI are 1E-3 and 261 for residents and 4E-4 and 26 for industrial workers. Exposure via direct dermal contact to the floor contributes most of the cumulative risk and HI for Building B. Limited downward migration through the flooring materials and high lipophilicity of PCBs increase the significance of human exposure via direct dermal contact with the building surfaces and dust ingestion from hand-to-mouth activities.

INTRODUCTION

Information for PCBs

- Chemical Structure
  - ◊ Two phenyl rings linked by a single carbon-carbon bond at the 1-1′ position
  - ◊ Substitution with 1 to 10 chlorine atoms
  - ◊ 209 distinct PCB congeners
  - ◊ Ten families of PCB isomers: mono-PCBs to deca-PCBs
- Aroclors
  - ◊ Commercial mixtures of PCBs synthesized in U.S.
  - ◊ Four digit number designation
    - ➢ "12" Designating the biphenyl structure
    - ➢ Followed by two digits identifying weight percent chlorine content
    - ➢ e.g., Aroclor 1260 contains 60% chlorine by weight
- Attributes - Heat stability, low reactivity, good dielectric and lubricating properties
- Industrial Uses - Electrical transformers and capacitors, hydraulic fluid, paints, inks, adhesives, paper products, etc.
- Manufacture – Began in 1930 and banned in 1977 in U.S.
- Environmental Concerns
  - ◊ Persistence in the environment, toxicity, and bioaccumulation
  - ◊ Common contaminant at hazardous waste sites
  - ◊ Risk from indoor air exposure (DTSC, 2002)
- Carcinogenicity
  - ◊ U.S. EPA (B2, probable human carcinogen), International Agency for Research on Cancer (2A, probably carcinogenic to humans), and California EPA classified PCBs as carcinogens (known to cause cancer and reproductive toxicity under the Safe Drinking Water and Toxic Enforcement Act of 1986)
  - ◊ Liver effects in rodents
  - ◊ Suggestive evidence in human workers – e.g. liver cancer
- Other Toxicities
  - ◊ Experimental animals and humans
  - ◊ Neurodevelopmental, endocrine, dermal, hepatic, and possibly immune system



Chemical Structure of PCBs

METHODS

Indoor Air Investigation

- Building Preparation
  - ◊ Ventilated 48 hours ⇨ closed 72 hours ⇨ sampled indoor air
  - ◊ Background – three outdoor air samples per event
- Indoor Air Sampling Methods
  - ◊ Method TO-10A
  - ◊ Sorbent cartridge containing polyurethane foam
  - ◊ Sampling Efficiency - Spiked with radiolabeled PCB standard
  - ◊ 24 hour, continuous-flow, and low-volume air sampler
- Analytical Methods
  - ◊ Building A – USEPA Method 1668A, GC/MS for 209 congeners
  - ◊ Building B – Modified USEPA Method 1668A, GC/MS for 90 congeners
  - ◊ Rationale for 90 Congeners:
    - ➢ Predominant congeners in Aroclor 1254
    - ➢ Previous indoor air data from Building A
    - ➢ Toxicity of PCB congeners (dioxin-like congeners)

Risk Assessment

- Indoor Air Exposure Assessment
  - ◊ Ratiometric risk calculation method from USEPA Preliminary Remediation Goal (PRG) User Guide (USEPA, 2004a)
  - ◊ Ambient Air PRGs for Aroclor 1254, cancer and non-cancer endpoints
- Surface Contact Exposure Assessment
  - ◊ Default soil exposure equations for residential scenario (USEPA, 1989)
  - ◊ Site-specific exposure assessment for industrial worker scenario
    - ➢ Average daily intake for non-carcinogenic effects (ADI_{der}) and lifetime average daily intake for carcinogenicity ($LADI_{der}$) via dermal contact

$$ADI_{der} \text{ or } LADI_{der} = \frac{C_B \times SA_d \times SAF \times TE \times EF \times ED \times ABS_d}{BW \times AT \times UCF}$$

    - ➢ Average daily intake for non-carcinogenic effects (ADI_{ing}) and lifetime average daily intake for carcinogenicity ($LADI_{ing}$) via incidental ingestion

$$ADI_{ing} \text{ or } LADI_{ing} = \frac{C_B \times SA_i \times SAF \times CF \times TE \times fdo \times fq_i \times EF \times ED}{BW \times AT \times UCF}$$

Site-Specific Exposure Parameters for Surface Contact Exposure Assessment for Building B [a]

		Residents			Industrial Workers	
		Child	Adult	Reference		Reference
Concentration in Building, mg/kg	C_B	105	105	Site-specific	105	Site-specific
Contact Frequency for Hand-to-Mouth Activities, events/day	CF	N/A	N/A	N/A	2	Site-specific
Skin Surface Area, cm^2/day	SA_d	2900	5700	DTSC, 2005	912 [c]	DTSC, 2005; Brouwer *et. al.*, 1999
Skin Surface Area, Ingestion, cm^2/event	SA_i	N/A	N/A	N/A	54 [d]	DTSC, 2005; Brouwer *et. al.*, 1999
Ingestion of Concrete as Dust, mg/day	$IR_{concrete}$	200 [b]	100 [b]	USEPA, 1989	54	(SA_i x CF x SAF)
Soil Adhesion Factor, mg/cm^2	SAF	0.2	0.07	USEPA, 2004b	0.5	Site-specific
Surface-to-Skin Transfer Efficiency	TE	1	1	Site-specific	1	Site-specific
Dermal Absorption Fraction	ABS_d	1	1	Site-specific	1	Site-specific
Fraction Transferred from Dermal-to-Oral	fdo	1	1	Site-specific	1	Site-specific

[a] Body Weight (BW), Averaging Time (AT), Exposure Frequency (EF), Exposure Duration (ED), Fractional GI Adsorption (fq_i), and Unit Conversion Factor (UCF) values were all standard defaults from RAGS, Part A (USEPA, 1989).
[b] Standard soil exposure assumptions were used for residential exposures to concrete surfaces. Deterioration of concrete surfaces was assumed to result in PCB concentrations in dust identical to those in concrete.
[c] Dermal contact with concrete surface = 16% of the default dermal contact area for workers (5700 cm^2).
[d] For the surface-to-dermal-to-oral pathway, the average dermal surface area of 16% of the surface area of both palms was assumed to contact the interior building surfaces with subsequent oral ingestion.

Toxicity Criteria for PCBs (USEPA, 2004a)

Toxicity Criteria for Aroclor 1254	Residents	Industrial Workers
Oral Cancer Slope Factor, (mg/kg/day)$^{-1}$	2	2
Oral Reference Dose, mg/kg/day	2E-5	2E-5
Cancer Ambient Air PRG, ng/m^3	3.4	7.2 [a]
Non-Cancer Ambient Air PRG, ng/m^3	73	102 [a]

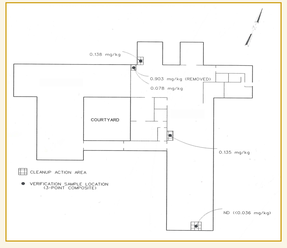
[a] Industrial Ambient Air PRG calculated from standard PRG equations and default exposure parameters

DATA and RESULTS

Site History

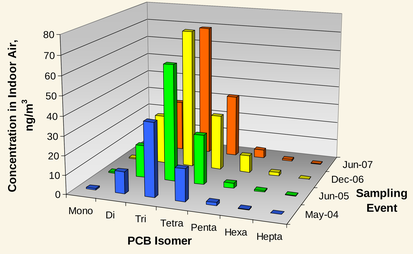
Building A – An industrial building with a mezzanine level in some areas

- Use
  - ◊ Previous – Jail, print shop, warehouse, and storage facility
  - ◊ Current – Empty
  - ◊ Proposed Future – Residential, condominium
- PCB Contamination
  - ◊ Potential Sources - Materials stored onsite, transformer fluid
  - ◊ Media - Concrete floors, soil below slab, and indoor air
  - ◊ Three Rounds of Remediation To Date – Washing of building surfaces, removal of floor and subsurface soil



Floor Plan of Building A

Data



Distribution of PCB Isomers in Indoor Air of Building A

Summary of Risk Assessment for PCB Contamination in Building A

Exposure Medium	Concentration	Exposure Route	Risk: Residents	Risk: Industrial Workers	HI: Residents	HI: Industrial Workers
Indoor Air	69 ng/m^3	Inhalation	2E-5 [a]	1E-5 [b]	0.9	0.7
Concrete	0.7 mg/kg	Ingestion	N/A [c]		N/A [c]	
	0.7 mg/kg	Dermal Contact	N/A [c]		N/A [c]	

[a] Risk estimated using TCDD-equivalents would be 2E-07
[b] Risk estimated using TCDD-equivalents would be 1E-07
[c] Incomplete exposure pathway assuming surfaces will be covered after redevelopment

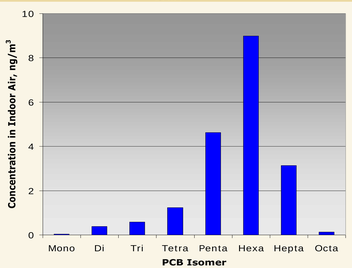
Site History

Building B – Over 250,000 sq. ft. floor space consisting of wood block, concrete, and steel plate; sub-surface sumps; several mezzanine levels; and elevated transformer platforms

- Use
  - ◊ Previous – Ship building, repair, and maintenance
  - ◊ Current – Empty
  - ◊ Proposed Future – Industrial
- PCB Contamination
  - ◊ Potential Sources - Electrical transformers, hydraulic fluid spills
  - ◊ Media – Concrete floors, wood block floors, indoor air, and soil in subsurface sumps
  - ◊ Remediation To Date - Chipping the concrete flooring and removal of some mezzanine flooring

Interior Views of Building B (insert shows opposing view)

Data



Summary of Risk Assessment for PCB Contamination in Building B (Feb-07)

Summary of Risk Assessment for PCB Contamination in Building B

Exposure Medium	Concentration	Exposure Route	Risk: Residents [c]	Risk: Industrial Workers	HI: Residents [c]	HI: Industrial Workers
Indoor Air	19 ng/m^3	Inhalation	6E-6 [a]	3E-6 [b]	0.3	0.2
Wood/ Concrete	105 mg/kg	Ingestion	3E-4	4E-5	67	3
		Dermal Contact	1E-3	3E-4	194	23
		Total	**1E-3**	**4E-4**	**261**	**26**

[a] Risk estimated using TCDD-equivalents would be 1E-05
[b] Risk estimated using TCDD-equivalents would be 6E-06
[c] Residential risk derived only to support deed restriction at the site

DISCUSSION AND CONCLUSIONS

- PCB contamination is ubiquitous in both buildings
- This work provides additional evidence that PCBs are of concern for indoor air exposure (DTSC, 2002)
- Human exposure via inhalation of PCBs in indoor air is a concern, since it is difficult to reduce exposure
- Isomer Distributions in the Two Buildings
  - ◊ Building A – predominantly tri-, tetra-, and penta-PCBs
  - ◊ Building B – predominantly penta-, hexa-, and hepta-PCBs
- Possible Reasons for Different Isomer Distributions
  - ◊ Different sources
  - ◊ Different weathering of the PCBs – physical conditions and length of time
  - ◊ Enrichment of more volatile PCB congeners in Building A indoor air
  - ◊ Adsorption of heavier congeners to dust particles
- Implications of Different Isomer Distribution
  - ◊ Different cancer potencies
  - ◊ Different bioaccumulation rates
- Difficulties in Risk Assessment
  - ◊ Contamination of matrices not commonly assessed at hazardous waste sites (building surfaces)
  - ◊ Site-specific exposure pathways and parameters
  - ◊ Lack of data on exposure to hard surfaces (e.g. wood and concrete) ⇨ Great uncertainty in risk estimates
  - ◊ Uncertainties in Risk Assessment – much greater for ingestion and dermal absorption from building surfaces than for inhalation of indoor air
- Difficulties in Remediation
  - ◊ Building A
    - ➢ Increase in PCB levels in indoor air after each round of remediation to remove potential sources
    - ➢ Sources of contamination not identified
  - ◊ Building B
    - ➢ Widespread contamination on/in building floors (wood and concrete)
    - ➢ Soil contamination in subsurface sumps
    - ➢ Huge building
    - ➢ Possible multiple sources
- Future Directions
  - ◊ Indoor air risk evaluation may be needed when PCBs are present
  - ◊ Validate assumptions used to evaluate exposures to building surfaces

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DISCLAIMER

The opinions and findings in this paper are those of the authors. They do not represent guidance or policy of the California Office of Environmental Health Hazard Assessment, California Department of Toxic Substances Control, or California Environmental Protection Agency.

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