Polychlorinated Biphenyls (PCBs)

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April 15, 2011
Overview

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- Distribution
- Sources
- Routes of Exposure
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- References
Background - What are PCBs?

History

- Historic industrial uses:
  - Coolants and insulating fluids for transformers and capacitors (especially fluorescent light fittings and electrical transformers)
  - Plasticizers in paints, rubber products, and cements
  - Adhesives, caulking, carbonless copy paper, floor finish, thermal insulation material, etc.

- Present in U.S. manufacturing from 1929 until 1976 when they were banned due to their persistence in both the environment and living organisms

- Banned by the Stockholm Convention on Persistent Organic Pollutants in 2001
Background - What are PCBs?

Physical Properties
- No known smell or taste; colorless to light yellow
- May exist as oily liquids, solids, or vapor in air
- Relatively water insoluble but lipid soluble

Chemical Properties
- Synthetic organochlorine chemicals
- Generally inert – resist acids & alkalis
- Thermal stability
- Non-volatile
- Relatively long half-life
Background – What are PCBs?

Chemical Properties Continued

• Composed of:
  – The biphenyl molecule (two six-carbon rings linked by a single carbon-carbon bond)
  – Chlorine atoms – which can substitute hydrogen atoms at any of the 10 non-bonded positions on the biphenyl molecule
  – Position names:
    • Ortho: 2, 2’, 6, and 6’
    • Meta: 3, 3’, 5, and 5’
    • Para: 4 and 4’
Background – What are PCBs?

Chemical Properties Continued

- 209 individual PCB congeners can be formed
  - Differentiated by number of chlorine atoms and their location on the biphenyl rings
  - Two major congener structural classes:
    - Planar congeners: two benzene rings in the same plane
      - Dioxin-like properties and generally most toxic congeners
    - Non-planar congeners: two benzene rings are a 90 degree angle to each other
Background – What are PCBs?

Mechanisms of Action:

• Biological mechanism of PCB health effects not completely understood

• Wide range of mechanisms of action depending on chlorine substitution pattern of congener
  – Estrogenic
  – Antiestrogenic
  – Neurotoxic
  – Dioxin-like
Background – What are PCBs?

Classification

• PCBs are part of a group of chemical substances known as Persistent Organic Pollutants (POPs)
Background – What are PCBs?

Important characteristics of all POPs

• **Persistent:**
  – Resist usual forms of degradation (physical, chemical and biological)
  – Can remain for many decades in the environment

• **Bioaccumulative:**
  – Fat soluble - thus tend to accumulate in the body at much greater levels than found in the ambient environment
  – Can bioconcentrate up to levels 100,000x greater

• **Likely to have Adverse Health Effects:**
  – Humans, animals, & ecosystems

• **Distant contamination:**
  – Most are semi-volatile and can move anywhere on the planet
    • Wind currents
    • Water currents: ocean currents, rivers
    • Exposed species (i.e., birds, migratory mammals, etc.)
Distribution

• Adaptation from Deposition of air pollutants to the Great Lakes (First Report to Congress), EPA, 1994. Included in the World Federation of Public Health Associations, Persistent Organic Pollutants and Human Health, Washington,
Sources

• No natural sources of PCBs
• Entered the environment during their manufacture, use, and disposal as a *mixture* of congeners and impurities
• Despite their banning, release of PCBs into the environment is *still* possible from:
  – Hazardous waste sites
  – Illegal/improper disposal of industrial wastes and consumer products
  – Leaks from old electrical transformers containing PCBs
  – Burning of some wastes in incinerators
Routes of Exposure

• All humans are exposed to PCBs on a daily basis
  – The question is not if there is exposure, but rather, how much?

• Ingestion
  – Assumed primary route
  – PCBs bioaccumulate in animal products, which may then be consumed by humans
  – May also accumulate in breast milk and be transmitted to infants through breast-feeding

• Inhalation

• Dermal absorption

• Three major pathways:
  – Environmental, accidental, and occupational
Toxicokinetics

• Absorption:
  – Absorbed readily in the gastrointestinal tract
  – Rate generally increases with extent of congener chlorination
  – Mechanism of absorption by the inhalation and dermal routes of exposure is unknown

• Metabolism:
  – Primarily hepatic metabolism
  – Rate of metabolism highly dependent on Cl substitution pattern of congener
  – Takes years, sometimes decades to clear

• Storage
  – Concentrate in adipose tissue due to lipophilic nature

• PCB half-life in the human body
  – Varies by congener and physiological processes of person
  – Ranges from a few years to ~20 years
Health Effects - Acute

Acute

- No reports of effects in humans following acute (short-term) exposure to PCBs are available
- Animal studies have reported acute effects on the liver, kidney, and central nervous system (CNS) from oral exposure to PCBs
- Acute animal tests in rats have shown PCBs to have moderate acute toxicity from oral exposure
Health Effects - Chronic

Systemic:
- Respiratory
- Cardiovascular
- Gastrointestinal
- Hematological
- Musculoskeletal
- Hepatic
- Renal
- Endocrine
- Dermal
- Ocular
- Body Weight

Immunological and Lymphoreticular
- Neurological
- Reproductive
- Developmental
- Genotoxic

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Health Effects

Evidence for various PCB-associated diseases:

- Cancer:
  - PCBs are complete carcinogens and act as general cancer promoters
  - Assumed to increase risk for cancer of every kind
  - WHO – classified PCBs as “probable human carcinogens”
  - Types of cancers which studies have shown increased risk with PCB exposure:
    - Brain, Breast, Gastrointestinal, Liver/biliary, Lung, Malignant melanoma, Non-Hodgkin’s lymphoma, Thyroid, Prostate, Pancreatic
Health Effects

Evidence for various PCB-associated diseases:

• Recurrent Infections:
  – PCB exposure can suppress both the antibody and immune response
  – Human studies have shown exposure to PCBs results in great incidence in all types of infections:
    • Respiratory, skin, ear, measles, meningitis, chicken pox

• Neurobehavioral Effects:
  – In utero PCB exposure has been linked to:
    • Lower IQ and achievement tests
    • Low muscle tone and depressed reflexes
    • Poor performance on emotional and behavioral disorder measurement scales
  – Adult PCB exposure has been linked to loss of memory and IQ
Health Effects

Evidence for various PCB-associated diseases:

• Hypothyroidism:
  – Animal studies clearly show PCBs interfere with thyroid hormone at multiple sites
  – Human studies have shown relationship between PCB exposure and decreased thyroid function

• Infertility and Reproductive System Disorders
  – PCBs are potent inhibitors of the synthesis of testosterone
  – PCB exposure has been associated with:
    • In men: reduced sperm mobility; decreased testosterone levels
    • In women: earlier menarche; increased menstrual cycle length
Health Effects

Evidence for various PCB-associated diseases:

• Cardiovascular Disease and Elevated Serum Lipids:
  – PCB exposure associated with:
    • Higher plasma triglyceride levels
    • Higher serum cholesterol levels
    • Higher blood pressure
    • Increased CVD mortality

• Hypertension
  – PCB exposure associated with:
    • High blood pressure
    • Hypertension
Health Effects

Evidence for various PCB-associated diseases:

• Diabetes:
  – Dioxin exposure has been associated with elevated diabetes in multiple studies
  – Study with > 2,000 pregnant women showed dose-response relationship between PCB levels and diabetes

• Liver Disease
  – Several studies have found a positive association between serum PCB levels and elevated SGOT and GGTP
  – Studies by Fitzgerald et al. demonstrated that PCB exposure increases the rate of caffeine metabolism in the liver
Health Effects

Evidence for various PCB-associated diseases:

• Asthma:
  – PCB exposure is associated with a significant increase in risk of asthma
  – Mechanism responsible is not known

• Arthritis
  – Studies have shown PCB exposure to be associated with joint disease and inflammation
  – A study of Taiwanese men exposed to PCBs had elevated risk for developing arthritis and back problems due to intervertebral disc disease
  – Mechanism responsible is not known
Health Effects

Evidence for various PCB-associated diseases:

• Low Birth Weight:
  – Studies have shown maternal PCB exposure increases risk for giving birth to low birth weight babies
    • Apparent greater effect in males vs. females
    • Low birth weight associated with increased risk of several chronic diseases in adulthood (e.g., CVD, hypertension, and diabetes)
Public Health Complexities of PCBs

- **Exposures are a PCB mixture**
  - Each congener has its own profile of actions in biological systems
  - Without separation and quantification of individual PCB congeners during analysis, PCB concentrations can’t be directly correlated to toxic equivalency
  - Toxicity of mixture may be influenced by chemical interactions

- **Biomarkers are used for environmental exposure**
  - Biomarkers: serum, blood, breast milk, adipose tissue, and human hair
  - Debate over equivalency of PCB levels in these different biomarkers

- **Testing Issues**
  - Lipid adjustment
  - Lack of standardized measurement procedure for human PCB levels
  - Random error
  - Questionable value of testing at all (there is no treatment)


THANK YOU!

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