References: PCBs in Schools

Agency, U. S. E. P. (n.d.). "Exposure Levels for Evaluation of Polychlorinated Biphenyls (PCBs) in Indoor School Air." from https://www.epa.gov/pcbs/exposure-levels-evaluation-polychlorinated-biphenyls-pcbs-indoor-school-air.

Ampleman, M. D., et al. (2015). "Inhalation and dietary exposure to PCBs in urban and rural cohorts via congener-specific measurements." Environ Sci Technol **49**(2): 1156-1164.

Polychlorinated biphenyls (PCBs) are a group of 209 persistent organic pollutants, whose documented carcinogenic, neurological, and respiratory toxicities are expansive and growing. However, PCB inhalation exposure assessments have been lacking for North American ambient conditions and lower-chlorinated congeners. We assessed congener-specific inhalation and dietary exposure for 78 adolescent children and their mothers (n = 68) in the Airborne Exposure to Semi-volatile Organic Pollutants (AESOP) Study. Congener-specific PCB inhalation exposure was modeled using 293 measurements of indoor and outdoor airborne PCB concentrations at homes and schools, analyzed via tandem quadrupole GS-MS/MS, combined with questionnaire data from the AESOP Study. Dietary exposure was modeled using Canadian Total Diet Survey PCB concentrations and National Health and Nutrition Examination Survey (NHANES) food ingestion rates. For ΣPCB dietary exposure dominates. For individual lower-chlorinated congeners (e.g., PCBs 40+41+71, 52), inhalation exposure was as high as one-third of the total (dietary+inhalation) exposure. ΣPCB inhalation (geometric mean (SE)) was greater for urban mothers (7.1 (1.2) μg yr(-1)) and children (12.0 (1.2) μg yr(-1)) than for rural mothers (2.4 (0.4) μg yr(-1)) and children (8.9 (0.3) μg yr(-1)). Schools attended by AESOP Study children had higher indoor PCB concentrations than did homes, and account for the majority of children's inhalation exposure.

Brown, K. W., et al. (2016). "PCB remediation in schools: a review." Environ Sci Pollut Res Int **23**(3): 1986-1997.

Growing awareness of polychlorinated biphenyls (PCBs) in legacy caulk and other construction materials of schools has created a need for information on best practices to control human exposures and comply with applicable regulations. A concise review of approaches and techniques for management of building-related PCBs is the focus of this paper. Engineering and administrative controls that block pathways of PCB transport, dilute concentrations of PCBs in indoor air or other exposure media, or establish uses of building space that mitigate exposure can be effective initial responses to identification of PCBs in a building. Mitigation measures also provide time for school officials to plan a longer-term remediation strategy and to secure the necessary resources. These longer-term strategies typically involve removal of caulk or other primary sources of PCBs as

well as nearby masonry or other materials contaminated with PCBs by the primary sources. The costs of managing PCB-containing building materials from assessment through ultimate disposal can be substantial. Optimizing the efficacy and cost-effectiveness of remediation programs requires aligning a thorough understanding of sources and exposure pathways with the most appropriate mitigation and abatement methods.

Carpenter, D. O. (2006). "Polychlorinated biphenyls (PCBs): routes of exposure and effects on human health." Rev Environ Health **21**(1): 1-23.

The polychlorinated biphenyls (PCBs) are synthetic organochlorine chemicals that were useful industrial products in the past, but their production was ended because they persist in both the environment and living organisms. The PCBs are mixtures of up to 209 different components (congeners), depending on the number and position of chlorines around the biphenyl ring. The PCBs are fat-soluble substances to which everyone is exposed through ingesting animal fats, inhalation, or dermal contact. Exposure to PCBs suppresses the immune system, thereby increasing the risk of acquiring several human diseases. Both ortho-substituted and coplanar (dioxin-like) congeners are tumor promoters that enhance the effects of other carcinogenic substances. PCB exposure, especially during fetal and early life, reduces IQ and alters behavior. The PCBs alter thyroid and reproductive function in both males and females and increase the risk of developing cardiovascular and liver disease and diabetes. Women are at high risk of giving birth to infants of low birth weight, who are at high lifetime risk for several diseases. As knowledge of their toxic effects has grown faster than environmental levels have declined, PCBs remain dangerous contaminants.

Carpenter, D. O. (2015). "Exposure to and health effects of volatile PCBs." Rev Environ Health **30**(2): 81-92.

INTRODUCTION: Polychlorinated biphenyls (PCBs) are persistent, lipophilic contaminants that are known to increase risk of a number of human diseases. Although ingestion of animal fats is a major route of exposure, there is increasing evidence that inhalation of vapor-phase PCBs is also important and may be as or even more important than ingestion under some circumstances. METHODS: The evidence that inhalation of PCBs may cause cancer, heart disease, hypertension, and diabetes is reviewed and presented in this report. RESULTS: PCBs are known human carcinogens. A husband and wife, occupationally required to 'smell' PCB-containing oils, both developed thyroid cancer, malignant melanoma/severely melanocytic dysplastic nevus (a precursor to malignant melanoma) and the husband, a non-smoker, developed and died of lung cancer. The serum of both had highly elevated concentrations of lower chlorinated, volatile PCB congeners. In other studies, residents living near PCB-containing hazardous waste sites, and thus breathing PCB-contaminated air, have elevated rates of

hospitalization for cardiovascular disease, hypertension, diabetes and reduced cognitive performance, whereas other studies in defined populations show that there is an elevated risk of all of these diseases in individuals with elevated serum PCBs. CONCLUSIONS: These results are consistent with the conclusion that inhaled PCBs can increase risk of cancer, cardiovascular disease, hypertension, diabetes and reduce cognitive function.

Davies, H. and D. Delistraty (2016). "Evaluation of PCB sources and releases for identifying priorities to reduce PCBs in Washington State (USA)." Environ Sci Pollut Res Int **23**(3): 2033-2041.

Polychlorinated biphenyls (PCBs) are ubiquitously distributed in the environment and produce multiple adverse effects in humans and wildlife. As a result, the purpose of our study was to characterize PCB sources in anthropogenic materials and releases to the environment in Washington State (USA) in order to formulate recommendations to reduce PCB exposures. Methods included review of relevant publications (e.g., open literature, industry studies and reports, federal and state government databases), scaling of PCB sources from national or county estimates to state estimates, and communication with industry associations and private and public utilities. Recognizing high associated uncertainty due to incomplete data, we strived to provide central tendency estimates for PCB sources. In terms of mass (high to low), PCB sources include lamp ballasts, caulk, small capacitors, large capacitors, and transformers. For perspective, these sources (200,000-500,000 kg) overwhelm PCBs estimated to reside in the Puget Sound ecosystem (1500 kg). Annual releases of PCBs to the environment (high to low) are attributed to lamp ballasts (400-1500 kg), inadvertent generation by industrial processes (900 kg), caulk (160 kg), small capacitors (3-150 kg), large capacitors (10-80 kg), pigments and dyes (0.02-31 kg), and transformers (<2 kg). Recommendations to characterize the extent of PCB distribution and decrease exposures include assessment of PCBs in buildings (e.g., schools) and replacement of these materials, development of Best Management Practices (BMPs) to contain PCBs, reduction of inadvertent generation of PCBs in consumer products, expansion of environmental monitoring and public education, and research to identify specific PCB congener profiles in human tissues.

DellaValle, C. T., et al. (2013). "Environmental determinants of polychlorinated biphenyl concentrations in residential carpet dust." Environ Sci Technol **47**(18): 10405-10414.

Polychlorinated biphenyls (PCBs), banned in the United Sates in the late 1970s, are still found in indoor and outdoor environments. Little is known about the determinants of PCB levels in homes. We measured concentrations of five PCB congeners (105, 138, 153, 170, and 180) in carpet dust collected between 1998 and 2000 from 1187 homes in four sites: Detroit, Iowa, Los Angeles, and Seattle. Home characteristics, occupational history, and demographic information were obtained by interview. We used a geographic information system to geocode addresses and determine distances to the nearest major road, freight route, and railroad; percentage of developed land; number of industrial facilities within 2 km of residences; and population density. Ordinal logistic regression was used to estimate the associations between the covariates of interest and the odds of PCB detection in each site separately. Total PCB levels [all congeners < maximum practical quantitation limit (MPQL) vs at least one congener >/= MPQL to < median concentration vs at least one congener > median concentration] were positively associated with either percentage of developed land [odds ratio (OR) range 1.01-1.04 for each percentage increase] or population density (OR 1.08 for every 1000/mi(2)) in each site. The number of industrial facilities within 2 km of a home was associated with PCB concentrations; however, facility type and direction of the association varied by site. Our findings suggest that outdoor sources of PCBs may be significant determinants of indoor concentrations.

Egsmose, E. L., et al. (2016). "Associations between plasma concentrations of PCB 28 and possible indoor exposure sources in Danish school children and mothers." Environ Int **87**: 13-19.

BACKGROUND: Polychlorinated biphenyls (PCBs) are ubiquitously present in the environment and are suspected of carcinogenic, neurotoxic and immunotoxic effects. Significantly higher plasma concentrations of the congener PCB 28 occur in children compared to adults. Exposure in schools may contribute to this difference. OBJECTIVE: To determine whether increased blood plasma concentrations of PCB 28 in Danish school children and mothers are associated with living in homes or attending schools constructed in the PCB period (1959-1977). METHODS: PCB 28 was analyzed in plasma samples from 116 children aged 6-11years and 143 mothers living in an urban and a rural area in Denmark and participating in the European pilot project DEMOCOPHES (Demonstration of a study to COordinate and Perform Human Biomonitoring on a European Scale). In Denmark, PCBs were used in construction in the period 1950-1977, and year of construction or renovation of the homes and schools was used as a proxy for indoor PCB exposure. Linear regression models were used to assess the association between potential PCB exposure from building materials and lipid adjusted concentrations of PCB 28 in plasma, with and without adjustment for potential confounders. RESULTS: Among the 116 children and 143 mothers, we were able to specify home construction period in all but 4 children and 5 mothers leaving 111 children and 138 mothers for our analyses. The median lipid adjusted plasma PCB 28 concentration was 3 (range: 1-28) ng/g lipid in the children and 2 (range: 1-8) ng/g lipid in the mothers. Children living in homes built in the PCB period had significantly higher lipid adjusted plasma PCB 28 concentrations compared to children living in homes built before or after the PCB period. Following adjustment for covariates, PCB 28 concentrations in children were 40 (95% CI: 13; 68) percent higher than concentrations

of children living in homes constructed at other times. Furthermore, children attending schools built or substantially refurbished in the PCB period also had significantly higher (46%, 95% CI: 22; 70) PCB 28 concentrations compared to children attending schools constructed before or after the PCB period, while their mothers had similar concentrations. Adjustment for the most prevalent congener, PCB 153, did not change this effect of home or school construction. When both home and school construction year were included in the models, the increase in lipid adjusted plasma PCB 28 for children living in or attending schools from the PCB period was no longer statistically significant. The individual effect of home and school construction periods could not be evaluated further with the available data. CONCLUSION: Our results suggest that PCB exposure in the indoor environment in schools and homes constructed during the PCB period may contribute significantly to children's plasma PCB 28 concentration. Efforts to minimize PCB exposure in indoor environments should be considered.

Gabrio, T., et al. (2000). "PCB-blood levels in teachers, working in PCB-contaminated schools." Chemosphere **40**(9-11): 1055-1062.

In order to get more information about potential health hazards due to indoor air PCBs the present study investigated the PCB indoor concentration in schools as well as the blood levels of 6 PCB-indicator congeners in teachers from these schools. 151 teachers (78 male and 73 female; mean age 48 years) from 3 contaminated and 2 control schools participated in the study. Maximal indoor air values for total PCBs (6 PCB-indicator congeners times 5) in schools ranged from 1587 to 10655 ng/m3. Blood analyses indicated an increase in mean PCB 28 level from 0.036 (control group) to 0.098 microg/l in teachers from a school with heavy contamination of low chlorinated PCB. But there was no significant increase of PCB 138, 153 and 180 in blood above the normal background concentrations in any of the contaminated schools (mean values of all groups: PCB 138 = 0.66, 153 = 0.95, 180 = 0.70 microg/l blood). The results of blood analyses and additional toxicokinetic calculations suggested that inhalative PCB-uptake in the most contaminated schools caused a minor increase above mean background-PCB concentrations in blood. In conclusion, despite high PCB indoor air levels in schools, there was only a moderate increase in blood concentrations of teachers, mainly due to congeners with low chlorination (PCB 28 to PCB 101).

Han, L., et al. (2016). "In utero exposure to polychlorinated biphenyls is associated with decreased fecundability in daughters of Michigan female fisheaters: a cohort study." Environ Health **15**(1): 92.

BACKGROUND: Multiple studies have suggested a relationship between adult exposures to environmental organochlorines and fecundability. There is a paucity of data, however, regarding fetal exposure to organochlorines via the mother's blood and fecundability of adult female offspring. METHODS: Data from a two-generation cohort

of maternal fisheaters was investigated to assess female offspring fecundability. Serum concentrations of polychlorinated biphenyls (PCBs) and 1,1-bis-(4-chlorophenyl)-2,2-dichloroethene (DDE) in Michigan female anglers were serially measured between 1973 and 1991 and used to estimate in utero exposure in their female offspring using two different methods. The angler cohort included 391 women of whom 259 provided offspring information. Of 213 daughters aged 20-50, 151 participated (71 %) and provided information for time intervals of unprotected intercourse (TUI). The daughters reported 308 TUIs (repeated observations), of which 288 ended in pregnancy. We estimated the fecundability ratio (FR) for serum-PCB and serum-DDE adjusting for confounders and accounting for repeated measurements. An FR below one indicates a longer time to pregnancy. RESULTS: Compared to serum-PCB of <2.5 microg/L, the FR was 0.60 for serum-PCB between 2.5-7.4 mug/L [95 % confidence intervals (CI) 0.36, 0.99], and 0.42 [95 % CI 0.20, 0.88] for serum-PCB >7.4 microg/L. Similar results were obtained using the alternative statistical method to estimate in utero serum-PCB. The association was stronger for TUIs when women planned a baby; FR = 0.50 for serum-PCB between 2.5-7.4 microg/L, [95 % CI 0.29, 0.89], and 0.30 [95 % CI 0.13, 0.68] for serum-PCB >7.4 mug/L. There was no relationship between in utero exposure to DDE and fecundability in daughters. CONCLUSIONS: Decreased fecundability in female offspring of fisheaters was found to be associated with PCB exposure in utero, possibly related to endocrine disruption in the oocyte and/or other developing organs influencing reproductive capacity in adulthood.

Herrick, R. F. (2010). "PCBs in school-persistent chemicals, persistent problems." New Solut **20**(1): 115-126.

The issue of polychlorinated biphenyls (PCB) exposures resulting from occupancy of PCB-contaminated buildings is not new, but the contribution of building materials to that contamination is largely unrecognized. A rapidly emerging base of evidence shows that PCBs can be widely found in caulking and paint in masonry buildings constructed or renovated from about 1950 to the late 1970s. These materials can cause extensive PCB contamination of the building interiors and surrounding soil, and people who teach, live, or attend school in these buildings can have elevated serum PCB levels. The potential risk associated with this source of PCB exposure is not known; however, it is worth noting that the specific PCB congeners found at high levels in the building environments, and in biological samples from the occupants, include some that are suspected of being potent neurotoxins. The U. S. Environmental Protection Agency (EPA) is moving to address this issue in schools; however, the costs of remediating contaminated buildings will pose a formidable obstacle to most school districts.

Herrick, R. F., et al. (2007). "Soil contamination from PCB-containing buildings." Environ Health Perspect **115**(2): 173-175.

BACKGROUND: Polychlorinated biphenyls (PCBs) in construction materials, such as caulking used around windows and expansion joints, may constitute a source of PCB contamination in the building interiors and in surrounding soil. Several studies of soil contamination have been conducted around buildings where the caulking has been removed by grinding or scraping. The PCBs in soil may have been generated in the process of removing the caulking, but natural weathering and deterioration of the caulking may have also been a source. OBJECTIVES: The objectives of this study were to measure PCB levels in soil surrounding buildings where PCB-containing caulk was still in place, and to evaluate the mobility of the PCBs from caulking using the Toxicity Characteristic Leaching Procedure (U.S. Environmental Protection Agency Method 1311). DISCUSSION: We found soil PCB contamination ranging from 3.3 to 34 mg/kg around buildings with undisturbed caulking that contained 10,000-36,200 mg/kg PCBs. The results of the Toxicity Characteristic Leaching Procedure (leachate concentrations of 76-288 mg PCB/L) suggest that PCBs in caulking can be mobilized, apparently as complexes with dissolved organic matter that also leach off the caulking material. CONCLUSIONS AND RECOMMENDATIONS: Although these new findings are based on a small sample size, they demonstrate the need for a national survey of PCBs in building materials and in soil surrounding these buildings. Because the buildings constructed during the time the PCB caulking was in use (1960s and 1970s) include schools, hospitals, and apartment buildings, the potential for exposure of children is a particular concern. It is necessary to reconsider the practice of disposing of old PCB caulking removed during building renovations in conventional landfills, given the apparent mobility of PCBs from the caulking material. Disposal of some caulking material in nonhazardous landfills might lead to high PCB levels in landfill leachate.

Herrick, R. F., et al. (2004). "An unrecognized source of PCB contamination in schools and other buildings." <u>Environ Health Perspect</u> **112**(10): 1051-1053.

An investigation of 24 buildings in the Greater Boston Area revealed that one-third (8 of 24) contained caulking materials with polychlorinated biphenyl (PCB) content exceeding 50 ppm by weight, which is the U.S. Environmental Protection Agency (U.S. EPA) specified limit above which this material is considered to be PCB bulk product waste. These buildings included schools and other public buildings. In a university building where similar levels of PCB were found in caulking material, PCB levels in indoor air ranged from 111 to 393 ng/m3; and in dust taken from the building ventilation system, < 1 ppm to 81 ppm. In this building, the U.S. EPA mandated requirements for the removal and disposal of the PCB bulk product waste as well as for confirmatory sampling to ensure that the interior and exterior of the building were decontaminated. Although U.S. EPA regulations under the Toxic Substances Control Act stipulate procedures by which PCB-contaminated materials must be handled and disposed, the regulations apparently do not require that materials such as caulking be tested to determine its PCB content. This limited investigation strongly suggests that were this testing done, many buildings would be found to contain high levels of PCBs in the building materials and potentially in the building environment. The presence of PCBs in schools is of particular concern given evidence suggesting that PCBs are developmental toxins.

Herrick, R. F., et al. (2011). "Serum PCB levels and congener profiles among teachers in PCB-containing schools: a pilot study." Environ Health **10**: 56.

BACKGROUND: PCB contamination in the built environment may result from the release of PCBs from building materials. The significance of this contamination as a pathway of human exposure is not well-characterized, however. This research compared the serum PCB concentrations, and congener profiles between 18 teachers in PCB-containing schools and referent populations. METHODS: Blood samples from 18 teachers in PCB-containing schools were analyzed for 57 PCB congeners. Serum PCB concentrations and congener patterns were compared between the teachers, to the 2003-4 NHANES (National Health and Nutrition Examination Survey) data, and to data from 358 Greater Boston area men. RESULTS: Teachers at one school had higher levels of lighter (PCB 6-74) congeners compared to teachers from other schools. PCB congener 47 contributed substantially to these elevated levels. Older teachers (ages 50-64) from all schools had higher total (sum of 33 congeners) serum PCB concentrations than age-comparable NHANES reference values. Comparing the teachers to the referent population of men from the Greater Boston area (all under age 51), no difference in total serum PCB levels was observed between the referents and teachers up to 50 years age. However, the teachers had significantly elevated serum concentrations of lighter congeners (PCB 6-74). This difference was confirmed by comparing the congener-specific ratios between groups, and principal component analysis showed that the relative contribution of lighter congeners differed between the teachers and the referents. CONCLUSIONS: These findings suggest that the teachers in the PCB-containing buildings had higher serum levels of lighter PCB congeners (PCB 6-74) than the referent populations. Examination of the patterns, as well as concentrations of individual PCB congeners in serum is essential to investigating the contributions from potential environmental sources of PCB exposure.

Herrick, R. F., et al. (2016). "Review of PCBs in US schools: a brief history, an estimate of the number of impacted schools, and an approach for evaluating indoor air samples." Environ Sci Pollut Res Int **23**(3): 1975-1985.

PCBs in building materials such as caulks and sealants are a largely unrecognized source of contamination in the building environment. Schools are of particular interest, as the period of extensive school construction (about 1950 to 1980) coincides with the time of greatest use of PCBs as plasticizers in building materials. In the USA, we estimate that

the number of schools with PCB in building caulk ranges from 12,960 to 25,920 based upon the number of schools built in the time of PCB use and the proportion of buildings found to contain PCB caulk and sealants. Field and laboratory studies have demonstrated that PCBs from both interior and exterior caulking can be the source of elevated PCB air concentrations in these buildings, at levels that exceed health-based PCB exposure guidelines for building occupants. Air sampling in buildings containing PCB caulk has shown that the airborne PCB concentrations can be highly variable, even in repeat samples collected within a room. Sampling and data analysis strategies that recognize this variability can provide the basis for informed decision making about compliance with health-based exposure limits, even in cases where small numbers of samples are taken. The health risks posed by PCB exposures, particularly among children, mandate precautionary approaches to managing PCBs in building materials.

Hu, D. and K. C. Hornbuckle (2010). "Inadvertent Polychlorinated Biphenyls in Commercial Paint Pigments†." Environ Sci Technol **44**(8): 2822-2827.

A polychlorinated biphenyl (PCB) that was not produced as part of the Aroclor mixtures banned in the 1980s was recently reported in air samples collected in Chicago, Philadelphia, the Arctic, and several sites around the Great Lakes. In Chicago, the congener 3,3′-dichlorobiphenyl or PCB11 was found to be the fifth most concentrated congener and ubiquitous throughout the city. The congener exhibited strong seasonal concentration trends that suggest volatilization of this compound from common outdoor surfaces. Due to these findings and also the compound's presence in waters that received waste from paint manufacturing facilities, we hypothesized that PCB11 may be present in current commercial paint. In this study we measured PCBs in paint sold on the current retail market. We tested 33 commercial paint pigments purchased from three local paint stores. The pigment samples were analyzed for all 209 PCB congeners using gas chromatography with tandem mass spectrometry (GC-MS/MS). More than 50 PCB congeners including several dioxin-like PCBs were detected, and the PCB profiles varied due to different types of pigments and different manufacturing processes. PCB congeners were detected in azo and phthalocyanine pigments which are commonly used in paint but also in inks, textiles, paper, cosmetics, leather, plastics, food and other materials. Our findings suggest several possible mechanisms for the inadvertent production of specific PCB congeners during the manufacturing of paint pigments.

Publisher: Abstract available from the publisher.

Hunt, G., et al. (2016). "PCBs: exposures, effects, remediation, and regulation with special emphasis on PCBs in schools." Environ Sci Pollut Res Int **23**(3): 1971-1974.

Jacobson, J. L. and S. W. Jacobson (1996). "Intellectual impairment in children exposed to polychlorinated biphenyls in utero." N Engl J Med **335**(11): 783-789.

BACKGROUND: In utero exposure to polychlorinated biphenyls, a ubiquitous environmental contaminant, has been linked to adverse effects on neurologic and intellectual function in infants and young children. We assessed whether these effects persist through school age and examined their importance in the acquisition of reading and arithmetic skills. METHODS: We tested 212 children, recruited as newborns to overrepresent infants born to women who had eaten Lake Michigan fish contaminated with polychlorinated biphenyls. A battery of IQ and achievement tests was administered when the children were 11 years of age. Concentrations of polychlorinated biphenyls in maternal serum and milk at delivery were slightly higher than in the general population. A composite measure of prenatal exposure was derived from concentrations in umbilical-cord serum and maternal serum and milk. RESULTS: Prenatal exposure to polychlorinated biphenyls was associated with lower full-scale and verbal IQ scores after control for potential confounding variables such as socioeconomic status (P = 0.02). The strongest effects related to memory and attention. The most highly exposed children were three times as likely to have low average IQ scores (P <0.001) and twice as likely to be at least two years behind in reading comprehension (P = 0.03). Although larger quantities of polychlorinated biphenyls are transferred by breast-feeding than in utero, there were deficits only in associated with transplacental exposure, suggesting that the developing fetal brain is particularly sensitive to these compounds. CONCLUSIONS: In utero exposure to polychlorinated biphenyls in concentrations slightly higher than those in the general population can have a long-term impact on intellectual function.

IARC (2015). Polychlorinated Biphenyls and Polybrominated Biphenyls. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Lyon, France, IARC, WHO. **107**.

Klosterhaus, S., et al. (2014). "Polychlorinated biphenyls in the exterior caulk of San Francisco Bay Area buildings, California, USA." Environ Int **66**: 38-43.

Extensive evidence of the adverse impacts of polychlorinated biphenyls (PCBs) to wildlife, domestic animals, and humans has now been documented for over 40 years. Despite the ban on production and new use of PCBs in the United States in 1979, a number of fish consumption advisories remain in effect, and there remains considerable uncertainty regarding ongoing environmental sources and management alternatives. Using a blind sampling approach, 25 caulk samples were collected from the exterior of ten buildings in the San Francisco Bay Area and analyzed for PCBs using congener-specific gas chromatography-mass spectrometry (GC-MS) and chlorine using portable X-ray fluorescence (XRF). PCBs were detected in 88% of the caulk samples collected from the study area buildings, with 40% exceeding 50 ppm. Detectable PCB concentrations ranged from 1 to 220,000 ppm. These data are consistent with previous studies in other

cities that have identified relatively high concentrations of PCBs in concrete and masonry buildings built between 1950 and 1980. Portable XRF was not a good predictor of the PCB content in caulk and the results indicate that portable XRF analysis may only be useful for identifying caulk that contains low concentrations of Cl (</= 10,000 ppm) and by extension low or no PCBs. A geographic information system-based approach was used to estimate that 10,500 kg of PCBs remain in interior and exterior caulk in buildings located in the study area, which equates to an average of 4.7 kg PCBs per building. The presence of high concentrations in the exterior caulk of currently standing buildings suggests that building caulk may be an ongoing source of PCBs to the San Francisco Bay Area environment. Further studies to expand the currently small international dataset on PCBs in caulking materials in buildings of countries that produced or imported PCBs appear justified in the context of both human health and possible ongoing environmental release.

Koh, W. X., et al. (2015). "Human Serum from Urban and Rural Adolescents and Their Mothers Shows Exposure to Polychlorinated Biphenyls Not Found in Commercial Mixtures." Environ Sci Technol **49**(13): 8105-8112.

Although polychlorinated biphenyls are no longer sold as commercial mixtures, they are still being produced through modern manufacturing processes. We have previously shown that non-Aroclor PCB 11 is prevalent in indoor and outdoor air and sediment and detected in human serum. Here we report the prevalence of non-Aroclor PCB congeners (</=0.20 wt % in Aroclor) in human serum collected from urban and rural adolescents and their mothers. We hypothesized that additional non-Aroclor congeners are present in serum. Sera were extracted and detected for 209 PCBs using gas chromatography-tandem mass spectrometry. A list of 70 non-Aroclor PCB congeners was determined by measurement of original Aroclors. PCB 11, 14, 35, and 209 are the major dominating and most frequently detected congeners. PCB 14 and 35 have not been previously reported for environmental matrices. Adolescents have significantly lower total non-Aroclor PCB concentrations than mothers in East Chicago ($p < 0.001$) and Columbus Junction ($p = 0.008$). There are significant differences in non-Aroclor PCBs between East Chicago community and Columbus Junction community ($p < 0.001$). Non-Aroclor PCBs represent an average of 10% (and up to 50%) of total PCBs measured in serum. An average of 50% (and up to 100%) of these concentrations may be attributed to aryl azo and phthalocyanine paint pigments.

Koh, W. X., et al. (2016). "Serum polychlorinated biphenyls and their hydroxylated metabolites are associated with demographic and behavioral factors in children and mothers." Environ Int **94**: 538-545.

Factors contributing to the inter-individual variation in body burden of polychlorinated biphenyls (PCBs) and their hydroxylated metabolites (OH-PCBs) have not been fully elucidated. We examined associations between total serum concentrations of 209 PCBs, 64 OH-PCBs, and frequently detected individual congeners with demographic characteristics (age, gender, ethnicity and community of residence), body mass index (BMI or BMI percentile), and breastfeeding history in children and their mothers from 83 U.S. households. There was a significant positive association between age and concentrations of total PCBs and OH-PCBs in mothers. Non-Hispanics had significantly higher concentrations of total PCBs in mothers and OH-PCBs in children than Hispanics. Concentrations of total PCBs were significantly lower in mothers who had longer breastfeeding duration. Living in the Columbus Junction, Iowa community as compared to East Chicago, Indiana was associated with higher total PCBs in children, probably attributable to higher exposures at school. Lower concentrations of OH-PCBs were significantly associated with a higher BMI percentile in children. Congener-specific associations were observed for 30 PCB and 12 OH-PCB congeners and followed comparable trends. To our knowledge, this is the first study to examine factors contributing to variations in serum concentrations of total 209 PCBs and total OH-PCBs in children, as well as to examine ethnic differences in OH-PCB levels. Results from this study revealed that demographic characteristics, body mass index and breastfeeding history are factors that should be considered for human exposure and risk assessment of PCBs and OH-PCBs.

Kohler, M., et al. (2005). "Joint sealants: an overlooked diffuse source of polychlorinated biphenyls in buildings." Environ Sci Technol **39**(7): 1967-1973.

In October 2000, joint sealants containing polychlorinated biphenyls (PCB) were discovered in various public buildings in Switzerland. Triggered by this event, a nationwide comprehensive study was initiated by the Swiss Agency for the Environment, Forests, and Landscape, and 1348 samples of joint sealants as well as 160 indoor air samples from concrete buildings erected between 1950 and 1980 were analyzed. Out of 1348 samples, 646 (48%) contained PCB. In 279 (21%) samples, PCB concentrations of 10 g/kg and more were detected, and concentrations of 100 g/kg of PCB or more were found in 129 (9.6%) samples. These data indicate that PCB were widely used as plasticizers in joint sealants in Switzerland. In buildings constructed between 1966 and 1971, one-third of all joint sealants investigated contained more than 10 g/kg of PCB. PCB concentrations exceeding the limit of 0.050 g/kg above which material is required to be treated as PCB bulk product waste were reached by 568 samples (42%). PCB with a chlorine content between 45 and 55%, corresponding to mixtures such as Clophen A50, Aroclor 1248, and Aroclor 1254, were encountered in 316 samples (70%). In 42 cases (26%) where joint sealants containing PCB were present, clearly elevated PCB indoor air concentrations above 1 microg/m3 were encountered. In eight cases (5%), levels were higher than 3 microg/m3. The Swiss tentative guideline value of 6 microg/m3 (based on a daily exposure of 8 h) for PCB in indoor air was

exceeded in one case (0.6%). On the basis of this work, representing the first large-scale nationwide analysis of the issue of PCB-contaminated joint sealants, we estimate that there are still 50-150 t of PCB present in these materials, acting as diffuse sources. They are distributed over many hundreds of buildings all over the country and represent a significant but frequently overlooked inventory of PCB. In light of the Stockholm Convention on persistent organic pollutants that entered into force last year, reduction of the release of PCB from these widely used materials is an important issue to be addressed.

Lauby-Secretan, B., et al. (2013). Carcinogenicity of polychlorinated biphenyls and polybrominated biphenyls. Lancet Oncol **14**(4): 287-288.

Lehmann, G. M., et al. (2015). "Evaluating health risks from inhaled polychlorinated biphenyls: research needs for addressing uncertainty." Environ Health Perspect **123**(2): 109-113.

BACKGROUND: Indoor air concentrations of polychlorinated biphenyls (PCBs) in some buildings are one or more orders of magnitude higher than background levels. In response to this, efforts have been made to assess the potential health risk posed by inhaled PCBs. These efforts are hindered by uncertainties related to the characterization and assessment of source, exposure, and exposure-response. OBJECTIVES: We briefly describe some common sources of PCBs in indoor air and estimate the contribution of inhalation exposure to total PCB exposure for select age groups. Next, we identify critical areas of research needed to improve assessment of exposure and exposure response for inhaled PCBs. DISCUSSION: Although the manufacture of PCBs was banned in the United States in 1979, many buildings constructed before then still contain potential sources of indoor air PCB contamination. In some indoor settings and for some age groups, inhalation may contribute more to total PCB exposure than any other route of exposure. PCB exposure has been associated with human health effects, but data specific to the inhalation route are scarce. To support exposure-response assessment, it is critical that future investigations of the health impacts of PCB inhalation carefully consider certain aspects of study design, including characterization of the PCB mixture present. CONCLUSIONS: In certain contexts, inhalation exposure to PCBs may contribute more to total PCB exposure than previously assumed. New epidemiological and toxicological studies addressing the potential health impacts of inhaled PCBs may be useful for quantifying exposure-response relationships and evaluating risks.

Liebl, B., et al. (2004). "Evidence for increased internal exposure to lower chlorinated polychlorinated biphenyls (PCB) in pupils attending a contaminated school." Int J Hyg Environ Health **207**(4): 315-324.

External and internal exposure to six WHO-indicator congeners of polychlorinated biphenyls (PCB 28, 52, 101, 138, 153, 180) as well as subjective health complaints of a

group of 377 pupils attending a PCB-contaminated school were compared with a control group of 218 pupils attending a non-contaminated school. Indoor air of the contaminated school revealed total PCB concentrations (sum of six indicator congeners times 5) ranging between 690 and 20,800 ng/m3 (median 2044 ng/m3). The lower chlorinated congeners PCB 28, 52, 101 were the prevailing contaminants (median 33, 293, and 66 ng/m3). Using improved analytical procedures at least one of the lower chlorinated congeners could be detected in 95% of the blood samples of pupils attending the contaminated school. Median concentrations for PCB 28, 52, 101, and for the sum of lower chlorinated congeners were 6, 9, 5, and 22 ng/l blood plasma, respectively, whereas the corresponding values in the control group were all < 1 ng/l. In contrast, no significant differences were found for the higher chlorinated congeners (PCB 138, 153, 180) which were detected in 1-2 orders of magnitude higher concentrations in both groups. Due to the dietary intake of these congeners similar total PCB levels were found (95th percentile 1070 and 1010 ng/l plasma in participants of the contaminated and control school). Using the Giessen Subjective Complaint List for Children and Adolescents no statistically significant differences in health complaints were observed between both groups of children. It is concluded that exposure of pupils to PCB in indoor air of the contaminated school caused increased blood concentrations of lower chlorinated congeners. Compared to background levels the detected excess body burden was very low indicating no additional health risk. Exposure was not associated to any specific subjective complaints.

Lyng, N. L., et al. (2016). "Modelling the impact of room temperature on concentrations of polychlorinated biphenyls (PCBs) in indoor air." Chemosphere **144**: 2127-2133.

Buildings contaminated with polychlorinated biphenyls (PCBs) are a health concern for the building occupants. Inhalation exposure is linked to indoor air concentrations of PCBs, which are known to be affected by indoor temperatures. In this study, a highly PCB contaminated room was heated to six temperature levels between 20 and 30��C, i.e. within the normal fluctuation of indoor temperatures, while the air exchange rate was constant. The steady-state air concentrations of seven PCBs were determined at each temperature level. A model based on Clausius–Clapeyron equation,ln(*P*)=−_*H/RT+a0*, where changes in steady-state air concentrations in relation to temperature, was tested. The model was valid for PCB-28, PCB-52 and PCB-101; the four other congeners were sporadic or non-detected. For each congener, the model described a large proportion (R2>94%) of the variation in indoor air PCB levels. The results showed that one measured concentration of PCB at a known steady-state temperature can be used to predict the steady-state concentrations at other temperatures under circumstances where e.g. direct sunlight does not influence temperatures and the air exchange rate is constant. The model was also tested on field data from a PCB remediation case in an apartment in another contaminated building complex where PCB concentrations and temperature were measured simultaneously and regularly throughout one year. The model fitted relatively well with the regression of measured PCB air concentrations, ln(P) vs. 1/T, at varying temperature between 16.3 and 28.2 degrees C, even though the measurements were carried out under uncontrolled environmental condition.

MacIntosh, D. L., et al. (2012). "Mitigation of building-related polychlorinated biphenyls in indoor air of a school." Environ Health **11**: 24.

> BACKGROUND: Sealants and other building materials sold in the U.S. from 1958 - 1971 were commonly manufactured with polychlorinated biphenyls (PCBs) at percent quantities by weight. Volatilization of PCBs from construction materials has been reported to produce PCB levels in indoor air that exceed health protective guideline values. The discovery of PCBs in indoor air of schools can produce numerous complications including disruption of normal operations and potential risks to health. Understanding the dynamics of building-related PCBs in indoor air is needed to identify effective strategies for managing potential exposures and risks. This paper reports on the efficacy of selected engineering controls implemented to mitigate concentrations of PCBs in indoor air. METHODS: Three interventions (ventilation, contact encapsulation, and physical barriers) were evaluated in an elementary school with PCB-containing caulk and elevated PCB concentrations in indoor air. Fluorescent light ballasts did not contain PCBs. Following implementation of the final intervention, measurements obtained over 14 months were used to assess the efficacy of the mitigation methods over time as well as temporal variability of PCBs in indoor air. RESULTS: Controlling for air exchange rates and temperature, the interventions produced statistically significant ($p < 0.05$) reductions in concentrations of PCBs in indoor air of the school. The mitigation measures remained effective over the course of the entire follow-up period. After all interventions were implemented, PCB levels in indoor air were associated with indoor temperature. In a "broken-stick" regression model with a node at 20 degrees C, temperature explained 79% of the variability of indoor PCB concentrations over time ($p < 0.001$). CONCLUSIONS: Increasing outdoor air ventilation, encapsulating caulk, and constructing a physical barrier over the encapsulated material were shown to be effective at reducing exposure concentrations of PCBs in indoor air of a school and also preventing direct contact with PCB caulk. In-place management methods such as these avoid the disruption and higher costs of demolition, disposal and reconstruction required when PCB-containing building materials are removed from a school. Because of the influence of temperature on indoor air PCB levels, risk assessment results based on short-term measurements, e.g., a single day or season, may be erroneous and could lead to sub-optimal allocation of resources.

Marek, R. F., et al. (2014). "Variability in PCB and OH-PCB serum levels in children and their mothers in urban and rural U.S. communities." Environ Sci Technol **48**(22): 13459-13467.

Environmental exposures that affect accumulation of polychlorinated biphenyls (PCBs) in humans are complex and not fully understood. One challenge in linking environmental exposure to accumulation is determining variability of PCB concentrations in samples collected from the same person at different times. We hypothesized that PCBs in human blood serum are consistent from year to year in people who live in the same environment between sampling. We analyzed blood serum from children and their mothers from urban and rural U.S. communities (n = 200) for all 209 PCBs (median $\sum$PCBs = 45 ng/g lw) and 12 hydroxylated PCBs (median $\sum$OH-PCBs =0.09 ng/g fw). A subset of these participants (n = 155) also had blood PCB and OH-PCB concentrations analyzed during the previous calendar year. Although many participants had similar levels of PCBs and OH-PCBs in their blood from one year to the next, some participants had surprisingly different levels. Year-to-year variability in $\sum$PCBs ranged from -87% to 567% and in $\sum$OH-PCBs ranged from -51 to 358% (5th-95th percentile). This is the first study to report variability of all PCBs and major metabolites in two generations of people and suggests short-term exposures to PCBs may be a significant component of what is measured in human serum.

Marek, R. F., et al. (2017). "Airborne PCBs and OH-PCBs Inside and Outside Urban and Rural U.S. Schools." Environ Sci Technol **51**(14): 7853-7860.

PCBs appear in school air because many school buildings were built when PCBs were still intentionally added to building materials and because PCBs are also present through inadvertent production in modern pigment. This is of concern because children are especially vulnerable to the toxic effects of PCBs. Here we report indoor and outdoor air concentrations of PCBs and OH-PCBs from two rural schools and four urban schools, the latter near a PCB-contaminated waterway of Lake Michigan in the United States. Samples (n = 108) were collected as in/out pairs using polyurethane foam passive air samplers (PUF-PAS) from January 2012 to November 2015. Samples were analyzed using GC/MS-MS for all 209 PCBs and 72 OH-PCBs. Concentrations inside schools were 1-2 orders of magnitude higher than outdoors and ranged from 0.5 to 194 ng/m3 (PCBs) and from 4 to 665 ng/m3 (OH-PCBs). Congener profiles were similar within each sampling location across season but different between schools and indicated the sources as Aroclors from building materials and individual PCBs associated with modern pigment. This study is the first cohort-specific analysis to show that some children's PCB inhalation exposure may be equal to or higher than their exposure through diet.

Meyer, H. W., et al. (2013). "Plasma polychlorinated biphenyls in residents of 91 PCB-contaminated and 108 non-contaminated dwellings-an exposure study." Int J Hyg Environ Health **216**(6): 755-762.

BACKGROUND: In the1950s-1970s polychlorinated biphenyls (PCBs) were used in several countries as plasticizers in elastic sealants in buildings. OBJECTIVE: The primary objective was to study whether residents of PCB-contaminated dwellings had higher plasma levels of PCBs than their neighbours in non-contaminated dwellings. The secondary objective was to study possible associations between concentrations of PCBs in the indoor air and in the plasma of residents. METHODS: Stratified cross-sectional study of residents of a housing estate with four sections, of which only one section had PCB-containing sealants. The determination of 27 PCB congeners in plasma was performed among 134 exposed and 139 non-exposed residents. Air measurements were conducted in 104 flats. RESULTS: Significant differences in plasma PCBs between exposed versus non-exposed were found for most of the lower chlorinated and many of the higher chlorinated congeners. The median of sum of 27 PCBs was approximately four times higher in exposed compared with non-exposed residents. The elevated PCB concentrations persisted in multivariable analyses controlling for relevant cofactors. We found significant correlations between PCB indoor air concentrations and the PCB concentration in the plasma of the residents for ten of the lower chlorinated congeners. CONCLUSION: Our study confirms that indoor air exposure to PCBs from PCB containing sealants may result in a considerable internal PCBs exposure of the residents. For the first time we were able to demonstrate that the internal exposure to low chlorinated PCBs is significantly associated with the indoor air concentration of these congeners.

Mitro, S. D., et al. (2015). "Cumulative Chemical Exposures During Pregnancy and Early Development." Curr Environ Health Rep **2**(4): 367-378.

Industrial and consumer product chemicals are widely used, leading to ubiquitous human exposure to the most common classes. Because these chemicals may affect developmental milestones, exposures in pregnant women and developing fetuses are of particular interest. In this review, we discuss the prevalence of chemical exposures in pregnant women, the chemical class-specific relationships between maternal and fetal exposures, and the major sources of exposures for six chemical classes of concern: phthalates, phenols, perfluorinated compounds (PFCs), flame retardants, polychlorinated biphenyls (PCBs), and organochlorine pesticides (OCs). Additionally, we describe the current efforts to characterize cumulative exposures to synthetic chemicals during pregnancy. We conclude by highlighting gaps in the literature and discussing possible applications of the findings to reduce the prevalence of cumulative exposures during pregnancy.

Morrison, G. C., et al. (2017). "Partitioning of PCBs from air to clothing materials in a Danish apartment." Indoor Air.

Polychlorinated biphenyl (PCB) contamination of buildings continues to pose an exposure threat, even decades after their application in the form of calks and other building materials. In this research, we investigate the ability of clothing to sorb PCBs from contaminated air and thereby influence exposure. The equilibrium concentration of PCB-28 and PCB-52 was quantified for nine used clothing fabrics exposed for 56 days to air in a Danish apartment contaminated with PCBs. Fabric materials included pure materials such as cotton and polyester, or blends of polyester, cotton, viscose/rayon, and/or elastane. Air concentrations were fairly stable over the experimental period, with PCB-28 ranging from 350 to 430 ng/m(3) and PCB-52 ranging from 460 to 550 ng/m(3) . Mass accumulated in fabric ranged from below detection limits to 4.5 mg/g of fabric. Cotton or materials containing elastane sorbed more than polyester materials on a mass basis. Mass-normalized partition coefficients above detection limits ranged from 10(5.7) to 10(7.0) L/kg. Clothing acts as a reservoir for PCBs that extends dermal exposure, even when outside or in uncontaminated buildings.

Newman, D. M. (2010). "PCBs in schools: what about school maintenance workers?" New Solut **20**(2): 189-191.

Driven by environmental and parent activists, government agencies are paying increasing attention to the issue of PCBs in in-place caulk, particularly in school buildings. At the same time, there is insufficient consideration of the school maintenance workers and contractors who maintain and replace PCB caulk, even though they may constitute the school population with the highest exposures and risks. This commentary briefly assesses recent PCB-related developments at the U. S. Occupational Safety and Health Administration (OSHA), U. S. Environmental Protection Agency (EPA), and the New York State Education Department from an occupational health perspective.

Office of Senator Edward J. Markey (2016). The ABC's of PCBs: A Toxic Threat to America's Schools. Washington, D.C., United States Senate.

Osterberg, D. and M. K. Scammell (2016). "PCBs in schools-where communities and science come together." Environ Sci Pollut Res Int **23**(3): 1998-2002.

A novel aspect of the 8th International PCB Workshop at Woods Hole, MA, was the interaction between scientists and activists. While earlier workshops in this series had mentioned policy making, this Workshop focused on the problem of PCBs in schools. Focus on a problem brought an activist to give a plenary talk and facilitated a 1-day registration for other non-scientists to attend. The workshop was cohosted by the Superfund Research Programs at University of Iowa and Boston University and included active participation of each Program's Research Translation and Community Engagement Cores. A mandate of each National Institute of Environmental Health Science (NIEHS)-funded Superfund Research Program is bidirectional communication between scientists and community groups. The authors describe the events leading up to community involvement in the Workshop and the substance of the community engagement aspects of the workshop, in particular the participation by a parent-teacher group, Malibu Unites. The authors also discuss the value of such communication in terms of making important research accessible to those who are most affected by the results and poised to use it and the value of making scientists aware of the important role they play in society in addressing difficult questions that originate in community settings.

Peper, M., et al. (2005). "Neuropsychological effects of chronic low-dose exposure to polychlorinated biphenyls (PCBs): a cross-sectional study." Environ Health **4**: 22.

BACKGROUND: Exposure to indoor air of private or public buildings contaminated with polychlorinated biphenyls (PCBs) has raised health concerns in long-term users. This exploratory neuropsychological group study investigated the potential adverse effects of chronic low-dose exposure to specific air-borne low chlorinated PCBs on well-being and behavioral measures in adult humans. METHODS: Thirty employees exposed to indoor air contaminated with PCBs from elastic sealants in a school building were compared to 30 non-exposed controls matched for education and age, controlling for gender (age range 37-61 years). PCB exposure was verified by external exposure data and biological monitoring (PCB 28, 101, 138, 153, 180). Subjective complaints, learning and memory, executive function, and visual-spatial function was assessed by standardized neuropsychological testing. Since exposure status depended on the use of contaminated rooms, an objectively exposed subgroup (N = 16; PCB 28 = 0.20 microg/l; weighted exposure duration 17.9 +/- 7 years) was identified and compared with 16 paired controls. RESULTS: Blood analyses indicated a moderate exposure effect size (d) relative to expected background exposure for total PCB (4.45 +/- 2.44 microg/l; d = 0.4). A significant exposure effect was found for the low chlorinated PCBs 28 (0.28 +/- 0.25 microg/l; d = 1.5) and 101 (0.07 +/- 0.09 microg/l; d = 0.7). Although no neuropsychological effects exceeded the adjusted significance level, estimation statistics showed elevated effect sizes for several variables. The objectively exposed subgroup showed a trend towards increased subjective attentional and emotional complaints (tiredness and slowing of practical activities, emotional state) as well as attenuated attentional performance (response shifting and alertness in a cued reaction task). CONCLUSION: Chronic inhalation of low chlorinated PCBs that involved elevated blood levels was associated with a subtle attenuation of emotional well-being and attentional function. Extended research is needed to replicate the potential long-term low PCB effects in a larger sample.

Raffy, G., et al. (2016). "Semi-volatile organic compounds in the air and dust of 30 French schools: a pilot study." Indoor Air.

The contamination of indoor environments with chemical compounds released by materials and furniture, such as semi-volatile organic compounds (SVOCs) is less documented in schools than in dwellings - yet children spend 16% of their time in schools, where they can also be exposed. This study is one of the first to describe the contamination of the air and dust of 90 classrooms from 30 nursery and primary schools by 55 SVOCs, including pesticides, phosphoric esters, musks, polycyclic aromatic hydrocarbons (PAHs), polychlorobiphenyls (PCBs), phthalates and polybromodiphenylethers (PBDEs). Air samples were collected using an active sampling method, and dust samples were collected via two sampling methods (wiping and vacuum cleaning). In air, the highest concentrations (median > 100 ng/m3) were measured for diisobutyl-phthalate (DiBP), dibutyl-phthalate (DBP), diethyl-phthalate (DEP), bis(2-ethylhexyl)-phthalate (DEHP) and galaxolide. In dust, the highest concentrations (median > 30 mug/g) were found for DEHP, diisononyl-phthalate (DiNP), DiBP and DBP. An attempt to compare two floor dust sampling methods using a single unit (ng/m(2)) was carried out. SVOC concentrations were higher in wiped dust, but frequencies of quantification were greater in vacuumed dust. This article is protected by copyright. All rights reserved.

Robertson, L. W. and G. Ludewig (2011). "Polychlorinated Biphenyl (PCB) carcinogenicity with special emphasis on airborne PCBs." Gefahrst Reinhalt Luft **71**(1-2): 25-32.

Polychlorinated biphenyls (PCBs) are industrial chemicals used in various applications requiring chemical stability and have now become widely dispersed. Their characteristics of persistence, low water/higher lipid solubility, contribute to their ability to bioconcentrate and bioaccumulate. Traditionally PCBs have been regulated as food contaminants and the general population is primarily exposed by that route. PCBs in foodstuffs are generally higher chlorinated, resistant to metabolic breakdown, and elicit toxic changes that are thought to be predominantly receptor/parent PCB-driven. But for certain occupational exposures, and for those persons residing or working in contaminated buildings, and in large cities, an inhalation route of exposure may predominate. Airborne PCBs are, in contrast to foodborne PCBs, lower chlorinated, more volatile, and subject to metabolic attack. In this review, we have explored (geno-) toxic manifestations of PCBs typical of those found in air. Here metabolic conversion of the parent PCB to hydroxylated and other metabolic progeny appear to play a dominant role, especially in genotoxicity. We should be cognizant of the impact of exposures to airborne PCBs for those individuals who are occupationally exposed, for persons living near contaminated sites, for those who work or go to school in contaminated buildings, and especially cognizant of the young, the socio-economically disadvantaged and medically-underserved or nutritionally-deficient populations.

Shanahan, C. E., et al. (2015). "Inventory of PCBs in Chicago and Opportunities for Reduction in Airborne Emissions and Human Exposure." Environmental Science & Technology **49**(23): 13878-13888.

Tatsuta, N., et al. (2014). "Impacts of prenatal exposures to polychlorinated biphenyls, methylmercury, and lead on intellectual ability of 42-month-old children in Japan." Environ Res **133**: 321-326.

> BACKGROUND: The age-specific impacts of perinatal exposures to polychlorinated biphenyls (PCB), methylmercury (MeHg), and lead on child neurodevelopment remain controversial. Since we have already reported the prenatal effects of these chemicals on neurodevelopment in 3-day-old and 30-month-old children of a birth cohort, the following effects were analyzed in the 42-month-old children in the same cohort. METHODS: The Kaufman Assessment Battery for Children (K-ABC), comprised of four scales, was used to assess their intelligence and achievement. The relationships between the chemicals and K-ABC scores were analyzed using multivariate analyses. RESULTS: The median values of chemicals in cord blood of 387 children were 46.5 (5th and 95th percentiles, 16.7-115.7)ng/g-lipid for total PCB, 10.1 (4.3-22.2)ng/g for total mercury (THg), and 1.0 (0.5-1.8) mug/dL for lead. Of the highly chlorinated PCB homologs, 9 CBs was negatively correlated with the sequential and mental processing score of the K-ABC ($p<0.05$). There were no significant correlations between any K-ABC score and either THg or lead. The negative effect of 9 CBs remained even after adjusting for THg, lead, and other confounders. The K-ABC scores were significantly lower in the boys than in the girls, and the standardized beta of 9 CBs for the sequential and mental processing scores in multiple regression analysis was statistically significant in boys. CONCLUSIONS: These findings suggest that intellectual ability in the developmental stage may be impaired by prenatal exposures to highly chlorinated PCB homologs, especially in Japanese boys.

Thomas, K., et al. (2012). Polychlorinated biphenyls (PCBs) in school buildings: sources, environmental levels, and exposures, U.S. Environmental Protection Agency.

Vorkamp, K. (2016). "An overlooked environmental issue? A review of the inadvertent formation of PCB-11 and other PCB congeners and their occurrence in consumer products and in the environment." Sci Total Environ **541**: 1463-1476.

> Polychlorinated biphenyls (PCBs) are banned from production and use in most countries as they are persistent organic pollutants (POPs) of concern for environment and health. Recent research has pointed at a new environment issue resulting from the inadvertent formation of PCBs in certain processes, in particular the pigment production. PCB-11 is a major by-product in these processes, but PCB-28, PCB-52, PCB-77 as well as the nonachlorinated PCBs and PCB-209 have been found in pigments and consumer

products as well. In addition to environmental emissions via point sources, in particular related to industrial and municipal wastewater, atmospheric transport seems to be important for the global distribution of PCB-11. Thus, PCB-11 has also been detected in the polar regions. Worldwide air concentrations appear relatively uniform, but maxima have been found in urban and industrialized areas. Data on the uptake and accumulation of PCB-11 in the food chain are still inconclusive: Although food web studies do not show biomagnification, PCB-11 has been detected in humans. The human exposure might originate from the direct contact to consumer products as well as from the omnipresence of PCB-11 in the environment.

Wang, W., et al. (2013). "Exposure assessment and distribution of polychlorinated biphenyls (PCBs) contained in indoor and outdoor dusts and the impacts of particle size and bioaccessibility." Sci Total Environ **463-464**: 1201-1209.

The size fraction, bioaccessibility and associated human daily intake of PCBs via indoor and outdoor dust collected from two most populated urban centers of Pearl River Delta (PRD), China, were studied. The ΣPCBs levels (ng g(-1)) in indoor (51.9-264) and outdoor (4.02-228) dust in Guangzhou (GZ) were found higher than those in indoor (17.4-137) and outdoor (7.75-114) dust of Hong Kong (HK). Hexa-PCB was the largest contributor in dust samples (29-64%), followed by tri-PCB. The size fraction of PCBs indicated a high accumulation effect of particles less than 63 μm, while the lowest was found in 280-2000 μm. Toxic equivalency (TEQ) of dioxin-like PCBs in indoor dust of GZ and HK was 2 to 13 times higher than that in outdoor dust. The bioaccessibility of PCBs was determined as 5-61% depending on individual PCB congeners under study and bioaccessible PCB exposure was significantly lower than the estimate for total PCB. The daily intake of bioaccessible PCBs via dust ranged in 0.02-8.95 and 0.37-17.8 ng day $^{-1}$ in GZ while 0.01-4.95 and 0.16-9.83 ng day $^{-1}$ in HK for adults and children, respectively. Dust ingestion contributed to 0.49-10.6% of overall non-dietary PCB exposure (dust ingestion and inhalation) for adults while 12.9-35% for children, indicating the dominant contribution from inhalation.

Wilson, N. K., et al. (2001). "Levels of persistent organic pollutants in several child day care centers." J Expo Anal Environ Epidemiol **11**(6): 449-458.

Winneke, G. (2011). "Developmental aspects of environmental neurotoxicology: lessons from lead and polychlorinated biphenyls." J Neurol Sci **308**(1-2): 9-15.

The particular vulnerability of the developing nervous system for low-level exposure to chemicals is well established. It has been argued that some degree of developmental neurotoxicity was found for a large number of industrial chemicals. However, for only few of these, namely inorganic lead, arsenic, organic mercury and polychlorinated biphenyls (PCBs), human evidence is available to suggest that these may cause neurodevelopmental adversity and may, thus, be involved in contributing to neurodevelopmental disorders like autism, attention-deficit disorder, mental retardation or cerebral palsy. The focus of this overview is on PCBs and inorganic lead as developmental neurotoxicants at environmental levels of exposure. The adverse effects of inorganic lead on the developing brain have long been studied, and much emphasis has been on subtle degrees of mental retardation in terms of intelligence (IQ). The evidence is consistent, but the effect sizes are typically small. Research interest has also been devoted to studying aspects of "attention-deficit hyperactivity disorder" (ADHD) in children in relation to environmental exposure to lead in both cross-sectional and case-control studies. More recently, we have also studied core elements of ADHD according to ICD-10 and DSM-IV in relation to environmental exposure to lead, mercury and aluminum in asymptomatic school children in Romania. Both, performance measures (several attention tasks) and questionnaire-based behavior ratings from parents and teachers showed that lead, but not Hg or Al, was consistently and adversely associated with core elements of ADHD. These findings in asymptomatic children nicely fit into the overall pattern of observations and suggest that, apart from genetic influences, low-level exposure to lead contributes to this neurodevelopmental disorder. Polychlorinated biphenyls (PCBs) are persistent organic pollutants with lipophilic properties. Due to their persistence, they are still present in environmental media at potentially harmful concentrations, although production and use of PCBs was already banned in the early 1980s. Several prospective cohort studies-including our Dusseldorf study-have demonstrated that pre- and early postnatal exposure to PCBs is associated with deficit or retardation of mental and/or motor development, even after adjusting for maternal intelligence and developmental effects of the quality of the home environment. The pathophysiology is still unclear, although interference with thyroid metabolism during brain development is being discussed. Based on these reviews, three aspects, namely pre- vs. postnatal impact, effect scaling for comparative purposes, and integration of neurobehavioral findings into clinical and neuroscience contexts, are outlined as lessons learned from neurodevelopmental observations in children environmentally exposed to lead or PCBs.

Zhong, L., et al. (2017). "Volatile Organic Compounds (VOCs) in Conventional and High Performance School Buildings in the U.S." Int J Environ Res Public Health **14**(1).

Exposure to volatile organic compounds (VOCs) has been an indoor environmental quality (IEQ) concern in schools and other buildings for many years. Newer designs, construction practices and building materials for "green" buildings and the use of "environmentally friendly" products have the promise of lowering chemical exposure. This study examines VOCs and IEQ parameters in 144 classrooms in 37 conventional and high performance elementary schools in the U.S. with the objectives of providing a

comprehensive analysis and updating the literature. Tested schools were built or renovated in the past 15 years, and included comparable numbers of conventional, Energy Star, and Leadership in Energy and Environmental Design (LEED)-certified buildings. Indoor and outdoor VOC samples were collected and analyzed by thermal desorption, gas chromatography and mass spectroscopy for 94 compounds. Aromatics, alkanes and terpenes were the major compound groups detected. Most VOCs had mean concentrations below 5 microg/m(3), and most indoor/outdoor concentration ratios ranged from one to 10. For 16 VOCs, the within-school variance of concentrations exceeded that between schools and, overall, no major differences in VOC concentrations were found between conventional and high performance buildings. While VOC concentrations have declined from levels measured in earlier decades, opportunities remain to improve indoor air quality (IAQ) by limiting emissions from building-related sources and by increasing ventilation rates.