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Laboratory study of PCB transport from primary sources to settled dust

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HIGHLIGHTS

- Dust/source and dust/air partitions of PCBs were investigated in a 30-m^3 chamber.
- House dust and Arizona Test Dust on coated panels with/without PCBs were tested.
- Settled dust can adsorb PCBs from air.
- The house dust tested is a modest sink for PCBs.
- PCB's dust/source partition rate is much faster than its dust/air partition rate.

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ABSTRACT

Dust is an important sink for indoor air pollutants, such as polychlorinated biphenyls (PCBs) that were used in building materials and products. In this study, two types of dust, house dust and Arizona Test Dust, were tested in a 30-m^3 stainless steel chamber with two types of panels. The PCB-containing panels were aluminum sheets coated with a PCB-spiked primer or caulk. The PCB-free panels were coated with the same materials but without PCBs. The dust evenly spread on each panel was collected at different times to determine its PCB content. The data from the PCB panels were used to evaluate the PCB migration from the source to the dust through direct contact, and the data from the PCB-free panels were used to evaluate the sorption of PCBs through the dust/air partition. Settled dust can adsorb PCBs from air. The sorption concentration was dependent on the congener concentration in the air and favored less volatile congeners. When the house dust was in direct contact with the PCB-containing panel, PCBs migrated into the dust at a much faster rate than the PCB transfer rate due to the dust/air partition. The dust/source partition was not significantly affected by the congener's volatility. For a given congener, the ratio between its concentration in the dust and in the source was used to estimate the dust/source partition coefficient. The estimated values ranged from 0.04 to 0.16. These values are indicative of the sink strength of the tested house dust being in the middle or lower-middle range.

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1. Introduction

Polychlorinated biphenyls (PCBs) are man-made chemicals that persist in the environment. Commercial production of PCBs started in 1929 and was banned by the U.S. Congress in 1978. PCB-containing caulking materials and light ballasts were used in many buildings in the 1950s through the 1970. PCBs may be present in the caulk used in windows, door frames, masonry columns, and other materials in schools and other buildings. According to the U.S. Environmental Protection Agency (EPA) these caulking materials could contain up to 40% PCBs (U.S. EPA, 2015). PCBs have been identified as probable human carcinogens and they can affect the immune, reproductive, nervous, and endocrine systems (ATSDR, 2011; U.S. EPA, 2013). Air and dust levels of PCBs in buildings may account for a significant portion of exposure because PCBs are

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persistent in air and dust and people, especially children, spend more time indoors than outdoors (Vorhees et al., 1999; Garbrio et al., 2000; Liebl et al., 2004; Heinzow et al., 2007; Kuusisto et al., 2007; Srogi, 2008; Harrad et al., 2009; Meyer et al., 2013). Building materials, furniture, and other indoor environmental constituents (such as settled dust) can "pick up" PCBs through exposure to contaminated air or through direct contact with primary sources of PCBs. The adsorbed PCBs can be re-emitted into the air when the primary sources are removed or severely diminished. Many researchers and others have recognized the presence and importance of PCB sinks in PCB-contaminated buildings, but very little information is available about the related transport processes and the re-emission characteristics (AIHA, 2013; Herrick et al., 2004; EH&H, 2012; Frederiksen et al., 2012). For example, concentrations of PCBs in environmental media are not well-characterized and the link between the concentration of PCBs in caulking materials and PCBs in the air or dust is not well understood. Better understanding of PCB sinks is critical to exposure assessment and risk management for PCBs in buildings.

Dust is an important sink for indoor air pollutants. Dust differs from other sink materials in many ways. For instance, dust particles are very small in size, have a much greater surface area-to-volume ratio, can settle on source or non-source surfaces, and can be re-suspended, allowing them to contribute to inhalation exposure. Elevated PCB concentrations in indoor dust have been reported by many researchers worldwide (Vorhees et al., 1999; Wilson et al., 2001; Tan et al., 2007; Hwang et al., 2008; Rudel et al., 2008; Hover et al., 2009; Franzblau et al., 2009; Harrad et al., 2010; Roosens et al., 2010; Tue et al., 2010). The reported PCB content in dust varied greatly, from <1 to 890 μg/g. Vorhees et al. (1999) noticed that the fine fractions (<150 μm) of the dust samples were likely to contain higher concentrations of PCBs than the coarse fractions. Some mitigation processes such as using sand blasting to remove PCB paint may create PCB-containing dust (Hellman et al., 2008). PCBs in settled dust were presumed to be due to dynamic volatilization and condensation of PCBs in indoor environment. The bulk of PCBs found in the gas phase rather than the particle phase of air implies that the presence of PCBs in indoor air appears to be the results of volatilization (EH&E, 2012).

Transport of semivolatile pollutants to dust, either through air or through direct contact with a source, is often studied in small or microchambers (Clausen et al., 2004; Schripp et al., 2010; Kofoed-Sørensen et al., 2011; Rauert and Harrad, 2015). Clausen et al. (2004) used a 51-L glass chamber and a 35-mL Field and Laboratory Emission Cell (FLEC®) to study the sorption and subsequent re-emission of di(2-ethylhexyl)phthalate (DEHP). Similar methods were used by Schripp et al. (2010) for testing the transport of phthalates from plasticized polymer to settled dust. Rauert and Harrad (2015) used a 1.57-L stainless steel cylinder chamber to study the polybrominated diphenyl ethers (PBDEs) migration to indoor dust from plastic TV casing via volatillisation with subsequent partitioning, abrasion, and direct contact.

From 2010 to 2013, we have conducted a series of research to address several unresolved scientific questions that must be better understood to assess the magnitude of the PCB problems in buildings and to identify the best long-term solutions (Liu et al., 2015a, b). This paper summarizes the laboratory research results for PCB transport from primary sources to PCB sinks, including air to settled dust and sources to settled dust. The test method used in this study was similar to the methods used by Clausen et al. (2004) and Schripp et al. (2010), except that a 30-m^3 stainless steel chamber was used to allow multiple test panels to be placed in the chamber and to allow the panels to be removed from the chamber at different times. This research supports risk management decision-making and exposure assessment for PCBs in buildings.

2. Materials and methods

2.1. Test specimens

Two types of dust, i.e., house dust and Arizona Test Dust (ATD), were tested. The house dust was obtained from EPA National Exposure Research Laboratory (NERL). The dust sample was collected from vacuum cleaner bags from a local housekeeping service company in Research Triangle Park, North Carolina. The dust was sieved to <150 μm to remove large objects. The ATD (0–10 μm nominal diameters, Powder Technology, Inc., Burnsville, MN, USA) was a test dust made from Arizona sand. The ATD was included in the tests for evaluating the effect of the composition of the dust on PCB transfer. Physical and chemical properties of these two types of dust are summarized in Table S1, where it shows that the house dust contains 19.3% organic carbon as opposed to nearly no organic carbon in the ATD.

2.2. Chamber tests

One compartment (3.66 m wide, 3.05 m deep, and 2.74 m high) of a two-compartment stainless steel chamber (TCC) system was used to study the transport of PCBs to settled dust. The chamber and associated systems are constructed of non-emitting and non-shedding materials such as stainless steel and polytetrafluoroethylene (PTFE). An ultra-low particulate air (ULPA) filter and carbon bed provided air to the chamber that was free of particulate matter and voltile organic compounds (VOCs). The compartment used for the study was isolated and operated in the single-pass mode (i.e, no air re-circulation). Air flow was pulled through the compartment from the filter/carbon bed and exhausted to the building's ventilation system and controlled by an OPTO 22 data acquisition system (OPTO 22, Temecula, CA, USA). The flow rate setting varied from test to test, approximately 0.12–0.83 air changes per hour (ACH). The centrally-mounted ceiling fan was operated at 50% capacity to mix the air in the compartment uniformly. The chamber pressure, temperature, and humidity were not controlled. Flow rate, temperature, humidity, and pressure data inside the chamber were recorded continuously by the OPTO 22 during the tests.

Four dust tests were conducted by 0.25–2 g of dust being loaded on two types of panels, i.e., the PCB source panels and the PCB-free panels, respectively, and placed in the chamber together. Test conditions are summarized in Table 1. The source panels were coated with a PCB-spiked, oil-based primer or two-part polysulfide caulk. The PCB-free panels were coated with the same materials, but they were not spiked with PCBs. To add PCBs to the primer, a calculated amount of PCBs (Aroclor 1254 or 1242 standards purchased from AccuStandard Inc., New Haven, CT, USA) was mixed with the primer in a glass vial. Then, the vial was sealed and shaken in a paint shaker (Red Devil 5400, Red Devil Equipment Co., Plymouth, MN, USA) for 15 min. To add PCBs to the polysulfide caulk, a calculated amount of PCBs was added to the activator (Part B), which was then added to the resin (Part A). The two parts were mixed manually for approximately 5 min. A 21-cm diameter circle was painted with the paint or caulk on an aluminum sheet (25 cm × 25 cm × 0.028 cm) in the ventilated hood. The panel was cured in the hood at room temperature for five days before being loaded with dust and then placed in the chamber for testing. The PCB contents in the cured panels and the thickness and weight of the cured coating on panels were determined. During the test, an overnight air sample with the polyurethane foam (PUF) (pre-