

POLYCHLORINATED BIPHENYLS (PCBs):
A NEW HAZARD FOR HISTORIC BUILDINGS

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Abstract

Polychlorinated Biphenyls (PCBs) are hazardous organic compounds best known for their use in transformers and electrical capacitors because of their non-combustibility and flexibility. Lesser known, but widespread, use in caulking, finishes, and paint is now coming to light because of health risks, particularly associated with their prevalence in schools. Humans can be exposed to PCBs in numerous ways: through deteriorating caulk that makes its way to the soil by rain run-off, by breathing contaminated air, or by dermal contact with the material. This thesis will give a brief introduction to the history of PCBs in building construction from about 1950 to 1980 before production, sale, and disposal was regulated through the Toxic Substance Control Act (TSCA). The TSCA was one of a group of acts passed in the 1970's to improve the quality of the environment including the Clean Air Act, Federal Water Pollution Control Act, and Safe Drinking Water Act. Although it will decrease the amount in the environment, proper removal of PCBs may have implications for historic buildings. Because PCBs often migrate into porous adjacent substrate, original materials may have to be abated as well.

I was introduced to the topic of polychlorinated biphenyls during a summer internship when a client did not want to re-point within six inches of the windows on their historic building for fear of PCBs in the caulk. Partial re-pointing would have a detrimental effect on the appearance of the façade. This thesis will be illustrated with case studies of buildings containing PCBs and how they were managed. PCB abatement will continue to be a concern, especially in urban areas, because they are most commonly found in apartment buildings, schools, and larger office buildings. New York in particular has been examining PCB contamination in public schools. P.S. 199 in Manhattan, a 1963 building by noteworthy architect Edward Durell Stone is a prime example of New York City's push to remove PCBs from public schools. The building was part of an initial PCB pilot study. A second case study is Westgate Dormitory at MIT where several brick courses contaminated with PCBs were removed. Case study three will focus on PCB migration in a concrete building on UMass Amherst's campus. I will compare the techniques for abatement from the case studies to determine what parallels can be drawn. This thesis will give preservation instructions for buildings containing PCBs by providing a PCB abatement approach that is sensitive to the preservation of historic structures.

Introduction: New Hazards in the 19th & 20th Centuries

The end of the 19th and beginning of the 20th century was a time of innovation in construction technology. Stronger and cheaper synthetic building materials began to replace naturally occurring substances like wood, clays, and metals. One new group of chemicals to emerge in 1929 was polychlorinated biphenyls or PCBs. The flexibility, incombustibility, and insulating properties of PCBs led to their utilization in a wide array of applications from sealed uses in electrical transformers to open uses in building caulk. We now know PCBs are toxic to humans, animals, and their environment. Their use was banned by the Toxic Substances Control Act of 1976. Structures all over the world contain these hazardous materials, but there is still a lack of understanding of their properties and potential effects.

PCBs in building materials are a relatively new topic of discussion among environmental scientists and government agencies. A gap still exists between PCB research and public knowledge and perception. As scientists continue to evaluate the health and environmental impacts of these organochlorines¹, a greater awareness of their hazardous qualities is spreading to building owners, parents, and concerned citizens. The risk factor coupled with an uncertainty of the product's danger has opened the door for anxiety and caution from the public. An increased awareness of the material should commence with an intelligent dialogue without causing alarm. PCBs may present a real health danger, but it is important to recognize when there is a risk and when the compound is present in safe concentrations.

The uncertainty of the material makes its presence in historic structures challenging. Although other hazardous building materials have been found in historic structures, there are currently no guidelines for property owners faced with PCB abatement. Other well known hazards, such as lead paint, still trigger uneasiness in property owners and occupants, but there exist comprehensive ways to deal with them while maintaining sensitivity to buildings' historic value. A standard approach for PCB abatement in historic structures could save time and money and avoid confusion during renovation projects.

¹ Organic compounds that contains chlorine

I was inspired to research this topic after a summer internship with Building Conservation Associates, an architectural conservation firm with offices in New York, Philadelphia and Dedham, MA. Two historic buildings on Brown University's campus were being renovated, but concerns that the caulk might contain PCBs temporarily stalled progress. The buildings were built in the early twentieth century but had been renovated during the peak use of PCBs in this country and thus were at risk for contamination. The University was hesitant to test the material in question because a positive result for PCBs adds time, money, and aggravation to a project, while revealing a potentially unsafe environment for contractors, faculty, and students. Brown eventually tested and found no toxins, but the experience stuck with me. Once a known toxin has been identified it should be properly abated. By avoiding testing, the contamination remains unknown and the owner has no legal obligation to abate. Having PCB containing material on a building can be unsafe to occupants, but removing it improperly can also increase exposure. Planning for a historic building renovation with PCBs must take into account health risks, but also how the abatement will impact the historic integrity of the structure or resource.

Polychlorinated biphenyls present a problem to historic structures now and in the near future. A building may be nominated to the National Register of Historic Places when it is fifty years old; buildings of exceptional architectural merit may be listed sooner. Landmark designation laws of individual cities vary. In New York City, buildings may be landmarked after just 30 years. Because PCBs were used in caulk from the 1950s through the 1970s, many buildings just now reaching eligibility for listing may be contaminated and require abatement, although it may impact any buildings prior to this range as well. Masonry, concrete, and other porous structures demonstrate a unique challenge because PCBs from caulk seep into these adjacent substrates.² Additionally, the age of the caulk is significant because caulk that does not contain PCBs begins to deteriorate after about 20 years on a façade while PCB containing caulk remains flexible.

The preservation of structures built between the 1950's and 1970's already presents many challenges to the preservation field because the architectural value of these structures is

² Environmental Protection Agency, "PCB Guidance Reinterpretation." Last modified December 20, 2012. <http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/caulk/reinterpret.htm>

less widely accepted outside of the preservation community. If a building is contaminated with PCBs, having an easier and more comprehensive solution will keep clients more interested in considering preservation options.

Through an understanding of the material, its uses in historic structures, and in consideration of methods used by preservationists to abate other hazardous building materials, this thesis will propose a methodology for abating PCBs in historic buildings. Although PCBs are found in many building materials, this thesis will focus specifically on historic masonry structures with PCB contaminated caulk.³ After an analysis of abatement methods used in three well-documented case studies, recommendations may be drawn to assist with future preservation projects faced with this issue and its abatement.

³ For this thesis, the term caulk will be used as a term for both caulk and sealants used in building applications for joint sealing and gap filling purposes.

Chapter I: History and Properties of PCBs

The development of the modern chemical industry began gradually in the 19th century and rapidly accelerated in the first half of the 20th century. One leading company in the industry, Monsanto,⁴ was established in 1901. The Monsanto Chemical Company produced nearly all polychlorinated biphenyls in the environment today. Polychlorinated Biphenyls are man-made, persistent organic compounds dispersed throughout the world through Monsanto's products.⁵ PCBs are an organochlorine with the chlorine atoms attached to biphenyls. Although 209 were used commercially, refer to Figure 2.1 as an example of the chemical Monsanto primarily marketed PCBs under the name Aroclor.⁶ There were a total of twelve different Aroclor products produced by the company, each with a unique mixture.⁷ Because several Aroclors may be contained in a single caulk sample, the term PCB is used here as an all-inclusive, general term.

PCBs were used in a variety of ways. The production of PCBs for electrical capacitors and transformers began in 1929. For these applications, PCBs in an oily liquid form were desirable for their incombustibility and low conductivity.⁸ Architectural applications of PCBs emerged in the mid-twentieth century as the material found use in sealants, caulking, paints, adhesives, and light fixtures; PCB bearing caulk can be found on buildings primarily built between 1950 and 1980.⁹ The peak dates of PCB use in caulk correspond to a major worldwide construction boom after World War II. Buildings

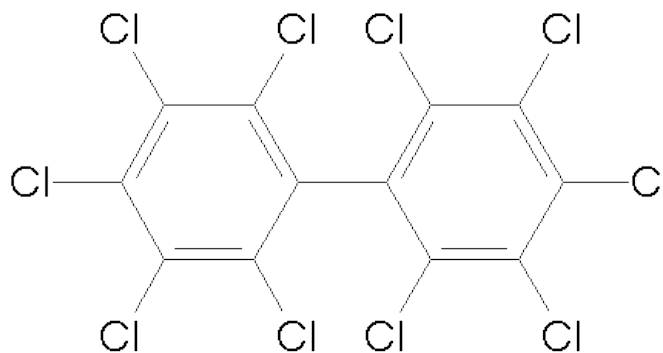


Figure 2.1: PCB Structure

Heidlore Fiedler, Bavarian Institute for Waste Research, Augsburg, Germany

http://www.chem.unep.ch/pops/POPs_Inc/proceedings/bangkok/FIEDLER1.html

⁴ Throughout its history, the company alternated between the names Monsanto and the Monsanto Chemical Company. For the purpose of this thesis, Monsanto or the Monsanto Chemical Company will be used interchangeably referring to the same company.

⁵ "There are no known natural sources of PCBs in the environment." Obaid Faroon, Syracuse Research Corporation, and James Olson. "Toxicological Profile for Polychlorinated Biphenyls (PCBs)." U.S. Dept. of Health and Human Services. ATSDR. November 2000. P. 1 <http://www.atsdr.cdc.gov/ToxProfiles/tp17.pdf>

⁶ For a full list of trade names for PCBs see Figure 2.3 Below

⁷ For a Complete table of Aroclors see Figure 2.2 Below

⁸ Environmental Protection Agency, "EPA Incinerator Approvals to Speed PCB Disposal," (Press Release February 10, 1981)

⁹ PCB Caulk refers to caulking containing 50ppm or greater concentration of PCBs

renovated during this period may contain PCBs in caulk as well. Although PCBs are found all over the United States, a higher percentage of buildings in the Northeast, Midwest, and West contain PCBs because of increased sealant use around windows due to cold winters.

PCB caulk is usually found in a few specific building types because of its properties. Larger public buildings, apartment complexes, and multi-building institutional settings such as universities, and schools contain PCB caulk whereas private homes tend not to have traces of these compounds.¹⁰ PCB caulk is most commonly found around windows and door frames, but can also be found in indoor applications.¹¹ "PCBs were added to the joint sealant materials in order to improve the flexibility of the material increase the resistance to mechanical erosion, and improve adhesion to other building materials."¹² PCBs gave caulk additional non-flammability, chemical stability, electrical insulating properties, and flexibility. Although the compounds introduced many attractive qualities, they were later found to be toxic for people and the environment.

The United States and many other countries introduced bans on PCB manufacturing, use, and disposal in the 1970's. In the United States, the ban came under the Toxic Substances Control Act of 1976, although the inclusion of PCBs in this act was not until 1978. The Monsanto Chemical Company voluntarily ceased production of PCBs just before the Toxic Substances Control Act passed and went into effect. Buildings constructed any time prior to 1980 should still be evaluated for PCB contamination as a precautionary measure.

¹⁰ Some single family homes may have PCB concentrations from other sources than caulk such as Fabulon floor finish, light ballasts, or a mastic used to hold carpeting down.

¹¹ Matthew Robson et al., "Continuing sources of PCBs: The Significance of Building Sealants," *Environmental International*, 36 (March 26, 2010) 506.

¹² Robson et al. "Continuing sources of PCBs: The Significance of Building Sealants," 506.

Table of Aroclors

CASRN	IUPAC Name	Type
12674-11-2	Aroclor 1016	Mixture
147601-87-4	Aroclor 1210	Mixture
151820-27-8	Aroclor 1216	Mixture
11104-28-2	Aroclor 1221	Mixture
37234-40-5	Aroclor 1231	Mixture
11141-15-5	Aroclor 1232	Mixture
71328-89-7	Aroclor 1240	Mixture
53469-21-9	Aroclor 1242	Mixture
12672-29-6	Aroclor 1248	Mixture
165245-51-2	Aroclor 1250	Mixture
89577-78-6	Aroclor 1252	Mixture
11097-69-1	Aroclor 1254	Mixture
11096-82-5	Aroclor 1260	Mixture
37324-23-5	Aroclor 1262	Mixture
11100-14-4	Aroclor 1268	Mixture
12767-79-2	Aroclor (unspecified)	Mixture

***Key to Table Columns**

CASRN
Chemical Abstracts Service (CAS) Registry Number.
IUPAC Name
The names presented in the table are the IUPAC names.
Type
The type of the PCB entity: Congener, Homolog, Mixture, Category.

Figure 2.2: Table of Aroclors the EPA

PCB Product List

Acedlor	Diador	PCB
Adkarel	Dicolor	PCB's
ALC	Diconal	PCBs
Apirolio	Diphenyl, chlorinated	Pheaoclor
Apirorlio	DK	Phenochlor
Arochlor	Duconal	Phenoclor
Arochlors	Dykanol	Plastivar
Arodor	Educarel	Polychlorinated biphenyl
Arodors	EEC-18	Polychlorinated biphenyls
Arubren	Elaol	Polychlorinated diphenyl
Asbestol	Electrophenyl	Polychlorinated diphenyls
ASK	Elemex	Polychlorobiphenyl
Askael	Elinol	Polychlorodiphenyl
Askarel	Eucarel	Prodelec
Auxol	Fenchlor	Pydraul
Bakola	Fendor	Pyraclor
Biphenyl, chlorinated	Fenocloro	Pyralene
Chlophen	Gilotherm	Pyranol
Chloretol	Hydol	Pyroclor
Chlorextol	Hyrol	Pyronol
Chlorinated biphenyl	Hyvot	Saf-T-Kuhl
Chlorinated diphenyl	Inclor	Saf-T-Kohl
Chlorinol	Inerteen	Santosol
Chlorobiphenyl	Inertenn	Santotherm
Chlorodiphenyl	Kanechlor	Santotherm
Chlorphen	Kanechlor	Santovac
Chorextol	Kennechlor	Solvol
Chorinol	Kenneclor	Sorol
Clophen	Leromoll	Soval
Clophenharz	Magvar	Sovol
Cloresil	MCS 1489	Sovtol
Clorinal	Montar	Terphenychlore
Clorphen	Nepolin	Therminol
Decachlorodiphenyl	No-Flamol	Therminol
Delor	NoFlamol	Turbinol
Delorene	Non-Flamol	
	Olex-sf-d	
	Orophene	

Figure 2.3: PCB Product List from the EPA

Chapter II: Environmental and Health Concerns

Environmental Concerns

A major environmental concern with regard to polychlorinated biphenyls is their chemical stability. This means that PCBs have the potential to persist and migrate through the environment for a long time. The chemical stability of PCBs is dependent on their level of chlorination, which is determined by the congeners present. There are 209 known congeners, defined as chemical compounds with very similar makeup and properties, that show a range of chlorination. Aroclors, which comprise many congeners, vary in chlorination as well. The number following the first two digits indicates the average chlorine content of the mixture; Aroclor 1254, for example, commonly used in caulk, has a chlorine content of 54%.¹³ Chlorination is significant in understanding the overall impact PCBs may have on the environment. The adsorption of PCBs on soil generally increases as the chlorination rises.¹⁴ "PCB concentrations in sediment and suspended matter have been shown to be greater than in the associated water column. Although adsorption may immobilize PCBs (especially the higher chlorinated congeners) for relatively long periods of time, eventual resolution into the water column has been shown to occur."¹⁵ Through the water and soil, aquatic organisms may be contaminated with PCBs. As in soil, fish tend to have the higher chlorinated PCBs in their bodies. When fish have been exposed to PCBs there is the potential for the compounds to move through the food chain to humans and other animals.

As the negative impacts from PCBs and other pollutants became increasingly concerning by the 1960's and 1970's, legislation was written to combat the environmental and health concerns. Pressure from environmentalists pushed the government to take action against PCB pollution. The Environmental Protection Agency (EPA) was created in 1970 under President Nixon by consolidating organizations and developing new positions. The mission of the EPA according to Nixon was "the establishment and enforcement of environmental protection standards... research on the adverse effects of pollution and on methods and equipment for

¹³ Faroon, Olson, and Syracuse Research Corporation "Toxicological Profile for Polychlorinated Biphenyls (PCBs)." 1.

¹⁴ Environmental Protection Agency, "Technical Factsheet on: POLYCHLORINATED BIPHENYLS (PCBs)" in *National Primary Drinking Water Regulations*, June 5, 2012: 2.

¹⁵ EPA, "Technical Factsheet on: POLYCHLORINATED BIPHENYLS (PCBs)" 2.

controlling it...strengthening environmental protection programs and recommending policy change, and assisting others, through grants, technical assistance and other means, in arresting pollution of the environment."¹⁶ As part of the fulfillment of these goals, a number of acts were passed in 1975, including the Clean Air Act, Federal Water Pollution Control Act, and the Safe Drinking Water Act, to remediate already established problems. Regulations for chemical products included those for drugs, food additives, and pesticide use passed through the Food and Drug Administration (FDA).¹⁷ The FDA is responsible for both protecting the public health and advancing it through research.¹⁸ These regulations predated any pertaining to polychlorinated biphenyls.

The Toxic Substance Control Act (TSCA) was the first act to include regulations pertaining to PCBs. Although the Act originally passed in 1976 by President Ford through the EPA, it was not until 1978, two years later, that a section was added concerning PCBs. The goal of the Act was to regulate substances, both natural and synthetic, with known health risks to living organisms. The Act filled a gap in regulations pertaining to chemicals and their entry into the commercial market. The TSCA achieved this by regulating the manufacturing, use, and disposal of chemicals to decrease human exposure and environmental impact. If a use is not explicitly stated in the TSCA it is prohibited. Disposal facilities for the chemicals were also specified in the act, but it took another three years until disposal facilities were available for PCB waste. The first two facilities were in Deer Park, TX and El Dorado, AK. The waste had been temporarily stored until a solution, to incinerate it at high temperatures, was devised in 1981.¹⁹ Disposal of PCBs had to occur in a particular way because they are "highly stable chemicals, they break down slowly and persist in the environment for a long time."²⁰ When PCBs are disposed of in regular landfills, the toxins can contaminate soil and water.

¹⁶ Environmental Protection Agency, "The Guardian: Origins of the EPA." Spring 1992.

¹⁷ EPA "Quarles Testifies on the Need for Toxic Substances Act." (Press Release, July 10, 1975)

¹⁸ Food and Drug Administration, "What We Do." Last updated June 19, 2012.

¹⁹ EPA "EPA Incinerator Approvals to Speed PCB Disposal"

²⁰ EPA "EPA Incinerator Approvals to Speed PCB Disposal"

Health Concerns

Polychlorinated Biphenyls have health risks associated with long-term exposure at moderate to high concentrations. PCB exposure affects both humans and animals. Animals have been found with cancer and other serious non-cancerous problems that affect the immune system, reproductive system, nervous system, and endocrine system, among others. In humans it is a likely carcinogen and causes immune, reproductive, neurological, endocrine and non-cancerous effects. Neurological damage can lead to learning disabilities and slowed development. When pregnant women or children are exposed to high levels of PCBs, certain glands and organs may not develop properly in the child. Because PCBs link to milk fats, mothers who breast feed can pass PCBs to their babies if it is in their systems. Children are also more susceptible to PCB exposure because the greater potential that they might ingest soil or dust during play. When PCBs enter the body, they may remain as PCBs or may be transformed by the body into metabolites which can be just as harmful as PCBs. Metabolites may remain in the body for months while PCBs may remain for years.²¹ The PCBs are primarily stored in the liver; evidence has shown that liver cancer may be connected to PCB exposure.²²

People come in contact with residual PCBs from caulk by ingesting dust or soil particles, breathing contaminated air, or physically touching PCB-containing material. PCBs enter the soil as caulk deteriorates. Rain runoff and air levels of PCBs rise due to the volatility of the aging compounds. "Small amounts of PCBs can be found in almost all outdoor and indoor air, soil, sediments, surface water, and animals."²³ Therefore, only elevated levels in these locations should be cause for alarm.

The most extreme risks for PCB exposure occur at past PCB production sites. The Monsanto Chemical Company has had a controversial history of releasing toxins into the environment.²⁴ Their PCB production sites in Sauget, IL, formerly called Monsanto, IL, and Anniston, AL likely caused the dangerous levels of PCBs found in blood of current residents to this day. These unsafe levels were caused by Monsanto knowingly disposing of PCBs improperly

²¹ Faroon, Olson, and Syracuse Research Corporation "Toxicological Profile for Polychlorinated Biphenyls (PCBs)." 5

²² Agency for Toxic Substances & Disease Registry, "Polychlorinated Biphenyls (PCBs)." Last updated March 3, 2011.

²³ Faroon, Olson, and Syracuse Research Corporation "Toxicological Profile for Polychlorinated Biphenyls (PCBs)." 4

²⁴ The company is also responsible for producing Agent Orange

as evident in company correspondence dating back to the 1960's.²⁵ The impact of these high PCB concentrations in those living near the plants is manifested in the high fetal death, immature births, and rare cancers seen in inhabitants of these locations. Fortunately, concentrations of this magnitude are uncommon for most communities; however, PCBs in caulk may still pose a health risk to building occupants and construction workers.

In addition to occupant exposure to PCBs, construction teams are also impacted. When PCB caulk was being applied to buildings by the initial crews, many workers came in direct contact with the substances. Some of these workers have been diagnosed with liver cancers and malignant melanomas.²⁶ In addition, workers who experienced dermal contact with PCBs at high concentrations developed skin conditions such as acne or rashes.²⁷ Sometimes PCBs were even added directly to the caulk onsite to increase the plasticity of the product. Workers involved in current renovation projects may encounter PCBs as well. These workers have the potential to inhale dust particles, come in physical contact with the PCB caulk or be exposed to PCBs in the air. These exposures are more likely to occur when the presence of PCBs is unknown and no precautions are taken.

Although PCBs are among the most researched chemicals in the health industry today, the full extent of human health risks is still unknown. Fortunately, the number of PCBs in the environment has already decreased compared to the 1970's²⁸, so the health risk should continue to diminish over time.

²⁵ The correspondence refers specifically to Anniston, AL. Ferrell, O.C., John Fraedrich, and Linda Ferrell. "Monsanto Attempts to Balance Stakeholder Interests," in *Business Ethics: Ethical Decision Making and Cases*. Ninth Edition. Mason, OH. Cengage Learning. 2013 p. 309

²⁶ Environmental Protection Agency, "Health Effects of PCBs" Last Updated 31 January 2013.

²⁷ Faroon, Olson, and Syracuse Research Corporation "Toxicological Profile for Polychlorinated Biphenyls (PCBs)." 5

²⁸ Gilbert Ross, "The public health implications of polychlorinated biphenyls (PCBs) in the environment." (November 2004) 276.

Chapter III: Awareness and EPA Regulations

The EPA has recently taken a strong interest in PCB contamination particularly because of its presence in schools. Although no additional regulations have passed, the EPA encourages testing and proper removal of caulk that is likely deteriorating. Typical building caulk lasts between fifteen and twenty years before becoming brittle; however, if old, flexible caulk is found then it will likely contain PCBs. When buildings are suspected to be PCB contaminated, a number of methods have been designed to detect their presence and concentration. Testing methods include soil, air, and blood testing as well as wipe analysis and laboratory analysis of bulk samples for identification.

Date of Construction

Date of construction is one way to identify the presence of PCBs in building. The first step is to determine if the building was constructed or renovated between 1929 and 1979 with particular attention paid to work between 1950 and 1979 in the case of caulk on masonry buildings. For a well documented building, looking through construction documents or correspondence about a building may indicate if Aroclor was specified.

Wipe

Wipe sampling is often a preliminary measure to determine the presence of PCBs on a structure. It is typically used in conjunction with another test because it is known to produce varying results when completed by "different samplers, on similarly contaminated surfaces having different textures and porosities, using no solvent or solvents having different polarities and using different kinds of wiping material such as filter paper, or cotton gauze."²⁹ To reduce variability in wipe testing, ASTM standard D6661-10 "Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling" is a uniform approach to the testing. The standard specifies its use for smooth, non-porous surfaces with an absorbent material. The absorbent material is wetted with a high purity solvent like isooctane or hexane. A wipe is taken from a 100cm² area then folded and placed in an amber glass sample container.³⁰ It is

²⁹ John H. Smith, "Wipe Sampling and Double Wash/Rinse Cleanup as recommended by the Environmental Protection Agency PCB spill Cleanup Policy." *Environmental Protection Agency*, (June 18, 1991): 5.

³⁰ ASTM, "D6661-10: Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling." West Conshohocken, PA: *ASTM International* (2010): 3

important to document, label, and include a control with every test. The sample is sent to a lab for testing and results. The method will indicate the presence of PCBs, but is not preferential for quantitative measurements as the test may indicate a significantly lower level due to the difficulty in sampling.

Bulk Sample

When building caulk has deteriorated and is scheduled to be removed, samples are regularly removed for determination of PCB content. A bulk sample is a definitive way to determine the presence of PCBs, but does not necessarily classify the magnitude of human exposure. If potentially hazardous material has been removed from the building, it may be tested using the approach in ASTM D6160-98 (Reapproved 2008). The two tiered approach quickly tests for the presence of PCBs then determines the concentration. The sample is extracted with a solvent then injected into the gas chromatograph.³¹ The presence of PCBs is detected by an Electron Capture Detector (ECD). The unknown sample is compared to a known sample to match the congener. "When quantification is required (Tier II), an external standards method (ESTD) is used. The quantitation technique typically requires a comparison of five peaks (minimum of three) between the chromatograms of an unknown sample and that of standard Aroclor obtained under identical conditions. Quantitation of either Aroclors 1016 or 1260 is performed using a five-point calibration of a mixed Aroclor standard containing Aroclors 1016 and 1260."³² When using this testing approach, careful comparison of the data is required by a professional who is experienced and knows what to observe. As was the case in air sampling, interferences may pose a major problem in Aroclor determinations using ECD. With caulk samples, phthalates in particular are a commonly seen interference since they are also used as plasticizers and show as broad late peaks.³³

For each test, 3mL of sample are required. A tier one test takes 12 minutes and a tier two test takes 17 minutes. The sample is diluted with 100µL of decachlorobiphenyl surrogate

³¹ ASTM, " D6160 –98 (Reapproved 2008): Standard Test Method for Determination of Polychlorinated Biphenyls (PCBs) in Waste Materials by Gas Chromatography," West Conshohocken, PA: *ASTM International* (2008): 1

³² ASTM, " D6160 –98 (Reapproved 2008): Standard Test Method for Determination of Polychlorinated Biphenyls (PCBs) in Waste Materials by Gas Chromatography," 2

³³ ASTM, " D6160 –98 (Reapproved 2008): Standard Test Method for Determination of Polychlorinated Biphenyls (PCBs) in Waste Materials by Gas Chromatography," 2-3.

working standard, 30mL of acetone/hexane, and then put in a vortex for 30 seconds.³⁴ Gas Chromatography is used to identify the samples and requires comparison to a standard chromatogram of known Aroclors. A knowledgeable scientist analyzes the data because the quantity is determined from interpretation of the peaks which takes practice and careful observation.

Air

Air sampling for PCBs is applicable for indoor and outdoor spaces. Although exterior applications of PCBs can be detected inside of buildings, elevated interior levels tend to indicate an interior source. When testing indoors, rooms are commonly tested in a closed system accompanied by a space trial simulating ventilation including opening windows to replicate a more accurate use of the space. ASTM Designation: D4861-11, "Standard Practice for Sampling and Selection of Analytical Techniques for Pesticides and Polychlorinated Biphenyls in Air" explains the process in which to test for the PCB chemicals in air. The complex nature of the test requires a specialized testing company with experience to complete the task. The chemicals are detected with the aid of a polyurethane foam (PUF) or a combination of PUF and granular sorbent. It is applicable for .001 to 50 $\mu\text{g}/\text{m}^3$ concentrations for 4 to 24 hour sampling periods.³⁵ After collected, the PCBs are extracted with diethyl ether in hexane and determined by gas chromatography/mass spectroscopy. Quantifying a specific PCB formulation is very difficult because of the complexity of the compounds.³⁶ Additional separation of pesticides may be required to isolate PCBs from other chemicals found in the sample.

The EPA also has two testing procedures Method TO-4A for high air volume and Method TO-10A for low air volume.

³⁴ ASTM, " D6160 –98 (Reapproved 2008): Standard Test Method for Determination of Polychlorinated Biphenyls (PCBs) in Waste Materials by Gas Chromatography," 6

³⁵ ASTM," D4861-11: Standard Practice for Sampling and Selection of Analytical Techniques for Pesticides and Polychlorinated Biphenyls," West Conshohocken, PA: *ASTM International* (2011): 3

³⁶ ASTM," D4861-11: Standard Practice for Sampling and Selection of Analytical Techniques for Pesticides and Polychlorinated Biphenyls,"3

Soil

Positive results from soil testing indicate possible PCB contamination on adjacent buildings. The allowable concentration of PCBs in soil is only 1ppm. Case study two tested caulk and masonry material after finding a PCB concentration of 1ppm in the soil outside of the dormitory.

Positive results from soil sampling can signify the past or current presence of PCBs in caulking material on a building. The incomplete removal of old sealants often leaves residual contamination in the soil, but PCBs can also reach the soil from runoff and volatilization. One European study selected 11 buildings built in the 1960's that had undergone caulk replacement within 1-3 years prior to the study.³⁷ The samples showed concentrations as high as about 29ppm, which decreased the farther from the building the samples were taken. The concentrations were also significantly higher on the south side of the building tested, suggesting that sun exposure is a critical element in the deterioration of PCB-containing caulk.³⁸ Soil is treated as solid waste, so after the particles are put through a process of solvents and a centrifuge to remove the soil, the presence of PCBs is determined through Gas Chromatography. The classification as solid waste also determines which facility is appropriate for proper disposal.

Blood

Blood tests alone do not indicate the source of PCBs. These tests can, however, offer pertinent information about human exposure to PCBs and health risks at a certain location. One example of how blood testing can reveal the presence of a PCB source is seen in a study testing residential buildings on Cape Cod in which the blood samples of residents were tested. The elevated PCB concentrations in one family led to further investigation of PCBs in that home, where they found PCBs in a floor finish. When the floor was sanded to be refinished, PCB containing dust particles were ingested by the family.³⁹ The collaboration of the blood serum

³⁷ Eero Priha, Sannamari Hellman, and Jaana Sorvari, "PCB contamination from polysulphide sealants in residential areas—exposure and risk assessment." *Chemosphere* 59 (January 14, 2005): 538.

³⁸ Priha, Hellman, and Sorvari, "PCB contamination from polysulphide sealants in residential areas—exposure and risk assessment." 542

³⁹ Rudel, Ruthann A., Liesel M. Seryak, and Julia G. Brody, "PCB-containing wood floor finish is a likely source of elevated PCBs in residents' blood, household air and dust: a case study of exposure." *Environmental Health* (2008)

test and other tests may indicate which PCBs a person is exposed to in a particular building versus which are from outside sources.

Overview

Many methods for PCB testing can yield valuable information about the potential PCB contamination on a building. Techniques are chosen based on ease of access, type of material that is being tested, and cost. The approximate cost for testing is \$550 per sample for an air analysis and \$100 per sample for wipe, caulk, and soil analyses.⁴⁰ Because multiple tests are often required to confirm results, costs can become a significant problem to owners. A building may have multiple areas of caulk, but that is not proof that each area is sealed with the same product. For large buildings, only representative samples will be taken, which may potentially misidentify the degree of contamination. Testing may occur before, during, and after abatement as well as in subsequent years as a way of monitoring the work.

⁴⁰Environmental Protection Agency, "Current Best Practices for PCBs in Caulk Fact Sheet—Testing in Buildings." Last Updated November 2012. <http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/caulk/caulktesting.htm>

Chapter IV: History of Hazardous Material Abatement

Many toxic substances used historically remain in the built environment today. Two commonly recognized hazards are asbestos and lead. Because of the early recognition of these hazards and their widespread use, solutions have been devised to mitigate damage when they are removed from in historic buildings. By looking at the precedents set by lead and asbestos removal programs, a solution can be suggested for PCB control in historic structures as well.

Lead Paint:

Lead paint has been used in the United States for centuries. Prior to the first lead manufacturers opening in the United States just after the Revolutionary War in Philadelphia, lead was being imported to the U.S..⁴¹ Lead pigment possesses desirable material qualities that were lacking in the commercial paint market. Lead pigments have excellent covering, adhesive and drying qualities.⁴² Red lead was a frequent primer for ferrous metals. In 1879 an evaluation of the paint industry stated that “the claimed advantage for the American white zinc over white lead are, that there is less or next to no danger to the health of workmen making or using it.”⁴³ Known risks of lead were established, but it would be another hundred years before any regulations on lead control were passed in the United States.

Lead-based paint was banned from use by the Toxic Substances Control Act in 1978. Although there are exceptions, if a building was constructed before 1978 it is highly likely to contain lead paint. These coatings are often hidden under more recent paint layers and may not pose a health threat. Lead paint becomes problematic as it deteriorates becoming friable leaving paint chips and dust in the room. Although both adults and children are susceptible to health risks associated with lead, children in particular need to be protected. Ingestion of lead dust and chips is the most common way for lead to get into the body, which is why children often show elevated lead levels. Preventing ingestion is important to limit exposure in children and adults.

⁴¹ “White lead and paints,” *The Great Industries of the United States*. Hartford: J.B. Burr & Hyde (1873): 498.

⁴² Park, Sharon C. And Douglas C. Hicks, “Preservation Brief 37: Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing.” *National Park Service, U.S. Department of the Interior* (1995 Revised in 2006): 2

⁴³ “White lead and paints” 499-500.

Implications for Historic Buildings

Lead paint is a more commonly known hazard than PCBs, most likely because it affects nearly all private residences built prior to 1978, whereas PCBs are usually located in larger commercial buildings or schools. Lead was also marketed under the names white or red lead, so the product matched the element. Even if people recognized Aroclor as hazardous product, they may not have associated it with PCBs and vice versa. The historic preservation community has written many articles about the proper ways to remove or encapsulate lead paint in historic structures while minimizing damage to original materials and retaining significance of historic fabric.

The removal of lead-based paint in historic buildings can compromise the character-defining feature of a home. During several architectural movements in the United States, decorative painting was applied in nearly all homes from upper class to lower class dwellings. Finishes also aid in dating alterations or identifying missing pieces around the house if an area is missing a particular layer. Some pigments can be connected to a specific time period. Removal of original finishes can destroy important information about a property's history that may not be documented elsewhere. With the presence of decorative finishes Preservation Brief 37, one of the National Park Service's many publications about preservation topics, recommends consulting a paint conservator to stabilize the lead paint and to cover it with a clear lead-free coating. When removal is the only option, research, analysis, and documentation are important tools for keeping a historical record.

Many health standards encourage the removal of as much lead paint as possible, but this removal may create a dangerous environment for the workers. It also costs more than other solutions. The Secretary of the Interior Standards for the Treatment of Historic Properties recommends minimal to no removal of lead paint, by managing the hazard through other techniques. "This is generally achieved through careful cleaning and treatment of deteriorating paint, friction surfaces, surfaces accessible to young children, and lead in soil."⁴⁴ The Preservation Brief outlines a three step approach for handling lead paint in a historic building

⁴⁴ Park and Hicks, "Preservation Brief 37: Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing." 3

- I. Identify the historical significance of the building and architectural character of its features and finishes;
- II. Undertake a risk assessment of interior and exterior surfaces to determine the hazards from lead and lead-based paint; and,
- III. Evaluate the options for lead hazard control in the context of historic preservation standards.⁴⁵

The historic finishes may give insight to the style or craftsman that worked on a particular building. By identifying the most integral parts of the house and ensuring their protection, some finishes may still have to be compromised. The presence of lead paint does not alone indicate a health risk. Methods for testing for lead paint, soil, or dust include x-ray fluorescence (XRF), chemical test, dust wipe, and atomic absorption spectroscopy.⁴⁶ If the XRF results show $1\text{mg}/\text{cm}^2$ the paint is considered lead-based. For a laboratory sample, if the weight of lead per weight of paint chip is .5% or greater it is considered lead-based (5,000ppm).⁴⁷ One square foot of dust is collected with a wipe then sent to a lab. The results should be below $40\ \mu\text{g}/\text{ft}^2$ for floors, $250\ \mu\text{g}/\text{ft}^2$ for window sills and $400\ \mu\text{g}/\text{ft}^2$ for window troughs.⁴⁸ The current regulation for blood levels in children is five micrograms per deciliter of lead, a recently reduced number from ten to find risks earlier. Lead is naturally found in soil, but is cause for concern if it reaches a level of 400ppm (significantly higher than the 1ppm allowed for PCBs). No action is required if lead-based paint is discovered in a test other than informing renters or buyers of the results.⁴⁹

Over exposure to lead puts a person's health at risk. Children may develop permanent damage to the brain and nervous system which leads to behavioral and learning problems, lower IQ, hearing problems, slowed growth, and anemia. Pregnant women may miscarry or have a premature birth. Adults may show signs of nervous systems effects, increased blood

⁴⁵ Park and Hicks, "Preservation Brief 37: Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing." 3

⁴⁶ Park and Hicks, "Preservation Brief 37: Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing." 4

⁴⁷ Environmental Protection Agency, "Testing Your Home for Lead in Paint, Dust, and Soil," (July 2000): 9

⁴⁸ Park and Hicks, "Preservation Brief 37: Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing."6

⁴⁹ Environmental Protection Agency, "Testing Your Home for Lead in Paint, Dust, and Soil." P5

pressure or hypertension, decreased kidney function, and reproductive problems.⁵⁰ Because of the many risks, knowledge of lead paint is essential to the safety of occupants and workers. Workers need to follow OSHA standard (29 CFR 1926) which limits the employee exposure to below fifty micrograms per cubic meter of air averaged over an 8-hour period.⁵¹ Workers may need to wear respirators or protective clothing depending on their exposure. Proper training and education is given to workers in frequent contact with lead. Total abatement is completed with chemicals, heat guns, or abrasive methods. The cost of removal, worker protection, and disposal are very expensive. Short term solutions include vacuuming, painting, and routine maintenance.⁵² For a complete list of abatement techniques refer to Table 4.1 below. Many options are available and through consultation with professionals, historic resources can be saved while maintaining a safe environment for occupants.

Table 4.1 MANAGING OR REMOVING LEAD-BASED PAINT IN HISTORIC BUILDINGS				
Interim solutions, the preferred approach, include a combination of the following:				
General Maintenance	Dust control	Paint stabilization	Soil treatment	Tenant education
Repair deteriorated materials; Control Leaks; Maintain exterior roofs, siding, etc. to keep moisture out of building; Perform Emergency repairs quickly if lead-based paint is exposed; Maintain building file with lead test data and reports, receipts or invoices on completed lead migration work.	Damp mop floor; wet broom sweep porches and steps; Damp dust window sills and window troughs; Wash down painted surfaces periodically (use tri-sodium phosphate or equivalent, if necessary); Clean or vacuum carpets regularly (use HEPA vacuum if lead dust returns); Undertake periodic inspection with annual dust wipe tests.	Wet-sand loose paint and repaint; Keep topcoats of paint in good condition; Selectively remove paint from friction & chewable surfaces (sills) and repaint; Use good quality latex, latex acrylic, or oil/alkyd paint compatible with existing paint; Consider more durable encapsulating paints and wall lining systems if necessary	Add bark mulch, sod or topsoil to bare dirt areas with high lead levels; Discourage children from playing in these areas by providing sand box or other safe areas; Do not plant vegetable garden in areas with lead in soil Be careful that pets do not track contaminated Soil inside house.	Notify tenants and workers as to the location of lead-based paint; Instruct tenants to keep property clean; Instruct tenants to notify owner or manager when repairs are necessary; Provide tenants with health department pamphlets on the hazards of lead based paint.

⁵⁰ All health information in this paragraph taken from "Learn about Lead" EPA Dec. 4. 2012. <http://www.epa.gov/lead/learn-about-lead.html#effects>

⁵¹ Occupational Safety and Health Administration "Standard (29 CFR 1926)." (May 4, 1993)

⁵² Park and Hicks, "Preservation Brief 37: Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing." 7

Hazard abatement removes the hazard - not necessarily all the paint or the feature, and may include:				
Paint Removal	Paint Encapsulation Enclosure	Replace Deteriorated Elements	Soil Treatment	Compliance
Remove deteriorated paint on friction, chewable, or impact surfaces to sound layer, repaint; Consider using the gentlest means possible to remove paint to avoid damage to substrate: wet sanding, low level heat guns, chemical strippers, or HEPA sanding; Send easily removable items (shutters, doors) off-site for paint stripping, then reinstall and paint.	Consider encapsulating paint with 20 years warranty to seal-in older paint; or use in combination with wall liners to stabilize plaster wall surfaces prior to repainting; Seal lead-based painted surfaces behind rigid enclosures, such as drywall, or use luan or plywood with new coverings over previously painted floors; Use rubber stair treads on painted steps	Remove only when necessary, seriously deteriorated painted elements such as windows, doors, and trimwork. Replace with new elements that match the historic in appearance, detailing, and materials, when possible; Replace component element of a friction surface (parting bead or stops of windows) or of impact surfaces (shoe moldings) with new elements	Remove contaminated soil around foundation to a depth of 3" and replace with new soil and appropriate planting material or paving; If site is highly contaminated from other lead source (smelter, sandblasted water tank) consult an environmental specialist as well as a landscape architect; Do not alter a significant historic landscape	Be aware of all federal, state and local laws regarding lead-based paint abatement, environmental controls and worker safety; Dispose of all hazardous waste according to applicable laws; Be aware that methods to remove lead-based paint can cause differing amounts of lead dust which can be dangerous to workers and residents
<i>This chart indicates the wide variety of treatments that can be used to control or eliminate lead-based paint hazards. For historic buildings, the least invasive method should be used to control the hazards identified during a risk assessment and are shown in the lighter shaded portion of the chart. The darker portions show the more invasive hazard control methods which must be carefully implemented to ensure that whenever possible, historic materials are protected. The total abatement of all surfaces is not recommended for historic buildings because it can damage historic materials and destroy the evidence of early paint colors and layering. Prepared by Sharon C. Park, AIA.⁵³</i>				

Asbestos

Asbestos is a mineral fiber used for its strength and heat resistance for insulation and as a fire retardant. It is used in many building materials including ceiling and floor tiles, roofing and siding shingles, insulation in attics, walls, or around pipes, patching material and cement. Use of asbestos could be found in buildings prior to the 20th century, but in 1900 an Austrian, Ludwig Hatschek invented a mechanized process for rolled and pressed asbestos-cement sheets which became popular in the United States after the US patent in 1907.⁵⁴ The shingles were fireproof, lightweight and inexpensive.

Although the material had widespread applications in the United States, the health concerns caused the industry to be shut down by the 1970's. Because asbestos is an airborne

⁵³ Park and Hicks, "Preservation Brief 37: Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing." 8

⁵⁴ Staveteig, Kaaren. "Roofing for Historic Buildings: Asbestos-Cement Shingles." *National Park Service, U.S. Department of the Interior*. (1999).

hazard, it was first identified as a hazardous pollutant on March 31, 1971 by the EPA in accordance with the Clean Air Act (CAA). The first version of the Asbestos NESHAP was written on April 6, 1973 (40 CFR Part 61, Subpart M.).⁵⁵ However, any building built or worked on prior to 1981 may contain asbestos.

Implications for Historic Buildings

The health risks associated with asbestos are lung cancer, mesothelioma, and asbestosis. All three conditions affect the lungs. Removal of asbestos falls under stricter guidelines than lead. An air-tight containment barrier seals the area from the outside. Complete removal of Asbestos Containing Materials (ACM) is common. A trained supervisor as well as trained workers must be on site during demolition or renovation. It is essential to check a contractor's credentials before work has begun to ensure they have proper expertise in the area. Careful explanation of the procedure prior to renovation and proper documentation of the process will increase safety for all involved.

The removal procedure is designed to minimize contamination in all locations of a building. The surfaces are wetted to decrease airborne particles. OSHA requirements (29 CFR 1926.1101 and 1910.1001) for workers include the use of personal protective equipment such as respiratory masks, coveralls, and gloves, worker training, bagging of waste and observing permissible exposure levels. An employee should not be exposed to an airborne concentration of asbestos in excess of .1 fibers per cubic centimeter of air as an eight-hour time-weighted average.⁵⁶ Measures are taken to protect uncontaminated areas adjacent to the site by having a buffer zone or "Clean Room" where workers shower and change out of their worker protection into their street clothes.

Asbestos removal in buildings can also be a complicated process. If asbestos is found in a historic building a three step approach may be taken as a guide.

- I. Remove asbestos-containing materials in negative pressure containment
- II. Remove asbestos-containing materials using the glove bag method

⁵⁵ "Environmental Protection Agency, "Asbestos NESHAP" Last updated November 14, 2012.

⁵⁶ Occupational Safety and Health Administration "Standard (29 CFR 1910.1001)." (May 4, 1993)

III. Encapsulate asbestos-containing materials.⁵⁷

Before significant historical elements are removed from a façade, a regional preservation officer may need to approve it. Encapsulation controls asbestos fibers by sealing it so they cannot enter the air. Because asbestos is only dangerous if it is deteriorating and friable, disturbing material in good condition will create a greater hazard than leaving it alone. It is best to either encapsulate as a precaution or create a maintenance plan to monitor asbestos hazard so that if it begins to break down fibers are not released into the air.

Although many uses of asbestos are insignificant to the historic integrity of a structure because they are in the walls or part of sacrificial elements, there are applications that contribute to the historic character of a building. Some of these examples might include roof and siding shingles. Asbestos was also added to concrete and asphalt for strength, which could contribute to significant elements on the façade.

Conclusion

Methods of lead and asbestos abatement may be adapted to suit the removal of Polychlorinated Biphenyls. A combination of guidelines from these two materials will help to form a plan when PCBs are found in historic structures. Whereas lead is often found on important architectural elements or decoration, asbestos and PCBs contribute to more sacrificial layers in a building system. Caulking material only lasts about 20 years before it has to be replaced and some forms of asbestos such as in insulation or behind walls, does not contribute to the architectural significance of a building.

The deterioration of all three materials enhances their potential danger so identifying toxic building materials before they deteriorate can prevent a health risk. I believe that using lead and asbestos abatement as a starting point can also facilitate the process for building owners. Having a mitigation plan for all hazardous substances in a building at once should save time and resources. It is also important for buildings owners to be able to identify potential

⁵⁷ U.S. General Services Administration. "Historic Preservation-Technical Procedures: Procedures for Removing Asbestos-Containing Materials." Last Modified February 24, 2012.

health risks before hiring a professional so that remediation techniques can be used and there is an understanding and recognition of the risks involved.

Chapter V: Abatement of PCBs

The EPA monitors PCB removal projects and has a four step process for the safe abatement of PCBs: 1) Prepare an Abatement Strategy, 2) Conduct Removal and Abatement Activities, 3) Handling, Storing, and Disposing Wastes, 4) Prepare and Maintain Documentation.⁵⁸ It was not until 2009 that the EPA released a comprehensive plan presenting information about PCBs in caulk and advice for building owners.⁵⁹

Bulk Waste vs. Remediation Waste

The EPA classifies PCB waste as either bulk waste or remediation waste depending on the material and PCB concentration. Bulk waste is materials that were manufactured with PCBs originally, but is also dependent on concentration. Therefore, if caulk has a PCB concentration of 50ppm or greater, it is considered bulk waste and needs to be disposed of at the proper regulated facility. If it has a concentration lower than 50ppm, it may remain in place or be disposed as remediation waste.⁶⁰ The adjacent substrate is also classified as remediation waste; however, under the EPA's 2012 reinterpretation, if the substrate is in contact with caulk, it may be classified as bulk waste, even if it has a concentration lower than 50ppm. If the PCB caulk accidentally becomes separated, the substrate may still be classified as bulk waste if stated in the abatement plan. Alternatively, if the caulk is intentionally separated from the substrate then it is classified as remediation waste. Prior to the reinterpretation, remediation waste was essentially treated as a spill and had to be separated from the caulk and brought to a different facility. The reinterpretation will make it easier to dispose of PCBs, speed up abatement projects, and lower costs. (See Figure 4.1) All material containing regulated PCBs must be removed from the building unless an alternative approach is approved by the EPA.

⁵⁸ Environmental Protection Agency, "Steps to Safe PCB Abatement Activities." Last Updated November 20, 2012.

⁵⁹ "Environmental Protection Agency, "PCBs in Caulk in Older Buildings." Last updated December 20, 2012

⁶⁰ "Current Best Practices for PCBs in Caulk Fact Sheet-Removal and Clean-up of PCBs in Caulk and PCB-Contaminated Soil and Building Material." Last Updated: 20 December 2012.

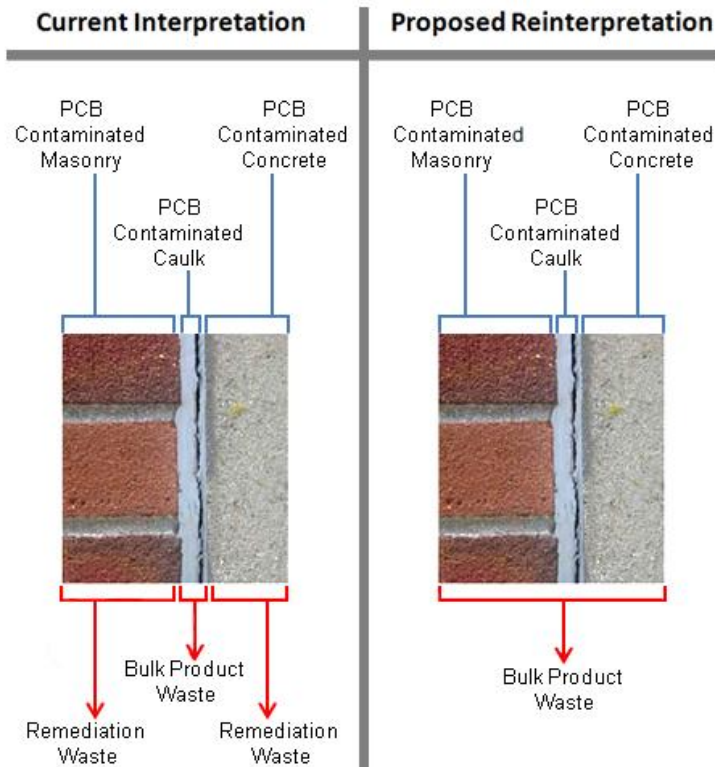


Figure 5.1: Reinterpretation of Bulk vs. remediation waste.
<http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/caulk/reinterpret.htm>

Disposal

PCB containing materials are disposed of based on their classification as either bulk product waste or remediation waste. Federal regulations for disposal may contrast those of state or local legislation so it is important to check both before choosing a method. For federal regulations three options for bulk waste disposal are found under 40 CFR 761.62.⁶¹ "The performance-based option allows for disposal of *PCB* bulk product waste in a TSCA incinerator, a TSCA chemical waste landfill, a RCRA hazardous waste landfill, under a TSCA approved alternate disposal method, under the TSCA regulated decontamination procedures; or in a facility with a coordinated approval issued under TSCA. Disposal under this option does not require unnecessary approval from the EPA."⁶² In some states, PCB caulk may be disposed of in a regular solid waste landfill without approval. The final option is a risk-based option which is case dependent and requires approval from the EPA.

⁶¹ CFR is the Code of Federal Regulations

⁶² EPA "Current Best Practices for PCBs in Caulk Fact Sheet - Disposal Options for PCBs in Caulk and PCB-Contaminated Soil and Building Materials"

Because remediation waste has a lower concentration of PCBs than bulk waste, the risk to the environment is less severe. There are also three disposal methods for remediation waste found under 40 CFR 761.61. "The self-implementing option links cleanup levels with the expected occupancy rates of the area or building where the contaminated materials are present. The disposal requirements for the self-implementing regulatory option vary based, among other things, on the type of contaminated material and concentration of PCBs in the materials."⁶³ The EPA should be notified, but they do not have to grant approval. The remediation waste may also use the performance-based option that "allows for disposal of the contaminated materials in either a TSCA chemical waste landfill or TSCA incinerator, through a TSCA approved alternate disposal method, under the TSCA regulated decontamination procedures, or in a facility with a coordinated approval issued under TSCA." The last option is again a risk-based cleanup and disposal used on a case by case basis with approval from the EPA.

Priority Considerations

PCB removal should be prioritized based on concentration and level of deterioration of the caulk. Removal of PCB containing materials on the exterior is typically to prevent indoor air levels of PCBs from rising and contaminated particles from getting into the soil. Generally, caulk containing the highest concentration of PCBs should be removed first, but caulk with lower concentrations that is deteriorating may pose a greater threat of contamination by getting into soil.⁶⁴ Additionally, environmental factors can accelerate caulk's deterioration. "A release of PCB contaminants into the air, or off-gassing, is especially likely in locations with direct sunlight."⁶⁵

Location of PCB contaminated caulk and the building function are also factors when considering priority. Caulk containing PCBs accessible to occupants through dermal contact or ingestion present the highest priority risk. Finally, the occupancy level of the building is considered. Abatement should be prioritized for high-occupancy areas. High occupancy rates are actually quite low. "High occupancy area means any area where PCB remediation waste has been disposed of on-site and where occupancy for any individual not wearing dermal and

⁶³ EPA "Current Best Practices for PCBs in Caulk Fact Sheet - Disposal Options for PCBs in Caulk and PCB-Contaminated Soil and Building Materials"

⁶⁴ Environmental Protection Agency, "Abatement Step 1: Prepare an Abatement Strategy." Last updated December 20, 2012.

⁶⁵ EPA "Abatement Step 1: Prepare an Abatement Strategy."

respiratory protection for a calendar year is: 840 hours or more (an average of 16.8 hours or more per week) for non-porous surfaces and 335 hours or more (an average of 6.7 hours or more per week) for bulk PCB remediation waste.⁶⁶ This easily includes schools, homes, workplaces, and many more. Recommended levels of PCB exposure in air depends on a combination of age and likelihood for other exposures a person may have to PCBs. For schools, The EPA suggests levels according to the chart below. Although, if someone has been in contact with PCBs through soil or dermal contact, the recommended exposure level for air decreases to compensate.

Age	1-2	3-5	6-12	12-14	15-18	19 and older
Guidance level (ng PCB/kg a day)	<70	<100	<300	<450	<600	<450 ⁶⁷

Abatement Tools

Tools selected for PCB abatement should minimize the potential exposure of PCBs to workers and occupants. The selection of which manual or power tools for use in caulk removal is greatly dependent on the consistency of the caulk: deteriorated and brittle versus flexible and intact. For manual tools, a utility knife is often sufficient to remove unweathered caulk, but a chisel or crowbar may be necessary for harder areas. Manual tools create fewer dust particles and do not reach high temperatures, so would not require additional worker protection. However, for large projects, manual tools are an inefficient approach. Electromechanical tools, such as an oscillating knife can rapidly cut through hard joints. Certain tools may produce dust or gases if heated to a level of 212°F or greater which would require additional personal protective equipment.

After all visible matter is removed, the substrate must be cleaned. Non-porous, smooth substrates such as a metal window or door frame should be wiped with a solvent.⁶⁸ A less

⁶⁶ 40 CFR 761.3

⁶⁷ Environmental Protection Agency, "Public Health Levels for PCBs in Indoor Air." Last Updated December 20, 2012.

common method used on some restoration projects is dry ice blasting to treat joint faces, but it is expensive and requires increased protective measures.⁶⁹

Protection

Some degree of protective measures will be required to protect workers, occupants and third parties. The level of personal protective equipment (PPE) required is dictated by the Occupational Safety and Health Administration (OSHA). OSHA was formed under the Occupational Safety and Health Act of 1970 to create safe working environments by making and enforcing standards and by providing training and education.⁷⁰ OSHA determines when PPE is required and to what degree based on permissible exposure limits (PEL) which is calculated based on a concentration over an 8-hour time frame. The equipment needed depends on the authorized plan, but includes chemical-resistant gloves, Tyvec coveralls, goggles, and a respirator.⁷¹ With mechanized tools, additional respirators may be necessary because of the increased number of dust particles in the air. To protect occupants and third parties from dust particles, an enclosed containment area with plastic covering and a HEPA filter should be used to control the dust. Additional vacuum attachments can be placed on electromechanical devices.



Figure 4.2 "Workers with respirators, ear muffs and other personal protective equipment (PPE)."

http://www.osha.gov/SLTC/etools/shipyard/ship_breaking/surfaceprep/index_sp.html

⁶⁸ Environmental Protection Agency, "Abatement Step 2: Conduct Removal and Abatement Activities." Last Updated December 26, 2012.

⁶⁹ Environmental Protection Agency, "Summary of Tools and Methods for Caulk Removal." Last updated November 30, 2012.

⁷⁰ "About Us" OSHA US Department of Labor. <http://www.osha.gov/about.html>

⁷¹ EPA "Abatement Step 2: Conduct Removal and Abatement Activities."

Chapter VI: Case Studies

Case Study 1: P.S. 199 Manhattan, NY



Figure 6.1.1: P.S. 199, Jessie Isador Straus School, Manhattan, NY

Photographed by Emily Sinitski, 2013

Introduction

Case study one, P.S. 199M or the Jessie Isador Straus School was designed by noteworthy architect Edward Durell Stone in 1963 (See figures 6.1.1 and 6.1.2 for images from 1964). It is located on the Upper West Side at West 70th and houses students from kindergarten to 5th grade. The buildings' white brick piers wrap around the exterior of the building, reminiscent of a Classical colonnade. Protruding brick headers on the piers give texture to the linear façade. The dark windows and bricks between these columns contrast the white columns emphasizing the depth. The building is topped with a concrete slab. Stone's attention to detail is showcased on the underside of the roof's overhang which has a concentric square pattern. These character-defining features remain on the building. Therefore, the Jessie Isador Straus School has maintained a high level of historic integrity. Even the replacement windows closely match those of the original design.



Figure 6.1.2: P.S. 199 Jessie Isador Straus School
Manhattan, NY
Photographed by Ezra Stoller, 1964
Image Courtesy of Ezra Stoller Archive (Esto)



Figure 6.1.3: P.S. 199 Jessie Isador Straus
School, Manhattan, NY
Photographed by Ezra Stoller, 1964
Image Courtesy of Ezra Stoller Archive (Esto)

During window replacement at P.S. 199M in 2008, the community first learned that caulk surrounding the window may have contained PCBs; however, the windows were still removed and the caulk replaced without an abatement plan or precaution in terms of protecting the soil.

In response to the potential PCB contamination at P.S. 199M and other New York City Schools, the *Daily News* investigated nine NYC schools for PCBs in caulk in March of 2008. Six of the nine buildings had PCB containing caulk. A caulk sample from the window replacements at P.S. 199M revealed levels greater than 200,000ppm.⁷² Local representatives demanded a response plan and continued promoting the story through media outlets. The toxic nature of PCBs in conjunction with a slow initial response from the city government caused parents and citizens to become very concerned about the safety of their schools.

To understand the degree of PCB contamination in New York City public schools, the EPA and the School Construction Authority of New York City reached an agreement in January of 2010 to combat PCBs throughout the public school system and to establish a plan for future cases.⁷³ The city began its research by selecting five buildings, one from each borough, for a pilot study.⁷⁴ At that time, there were already over 20 schools known to contain PCBs. The pilot study was initially created to analyze the effects of PCB contaminated caulk on indoor air quality, but it became obvious that there were multiple sources of PCBs when pre and post caulk remediation air samples showed high concentrations. The scope broadened to include another source of PCBs, leaking light ballasts, which were increasing the PCB concentrations in the air.

Summary of Results

The pilot study took place in two phases; phase one was between June 2010 and November 2010 and phase two occurred between April 2011 and November 2011. Phase one included a caulk survey, pre-remediation air and wipe sampling, soil samples, applied remedial alternatives such as encapsulation, patch and repair, and caulk removal, post-remediation air

⁷² The testing done by the Daily News was noted by the EPA and SCA, but did not follow an EPA approved plan, so there were limitations to how it could be interpreted.

⁷³ On January 19, 2010, The City of New York (the City) and the New York City School Construction Authority (SCA) reached an agreement regarding the assessment and remediation of PCB Caulk in public school buildings with the United States Environmental Protection Agency (USEPA), Region 2 (Consent Agreement and Final Order (CAFO), Docket Number TSCA-02-2010-9201) p. xi TRC Engineers, Inc. "Final Remedial Investigation Report for the New York City School Construction Authority pilot Study to Address PCB Caulk in New York City School Buildings." 21 August 2012.
http://www.nylni.org/images/FE/chain234siteType8/site203/client/Final_Revised_PCB_Pilot_Study_Remedial_Investigation_Report.pdf

⁷⁴ The Five selected buildings are P.S. 178X/176, P.S. 199M, P.S. 309K, P.S. 3R, and P.S. 183Q. p. ix TRC

and wipe samples, and an Interim Remedial Investigation Report.⁷⁵ Each caulk sample was taken with its own stainless steel utility knife and placed in a glass jar with a Teflon-lined cap.⁷⁶

The interior of P.S. 199M displayed deteriorating PCB caulk in 74 of the 244 surveyed areas. When some of the initial test locations did not contain caulk with PCB levels 50ppm or greater, the evaluation was expanded to more classrooms. The final room selection included classrooms 116, 118, 202, 308, 316, 320, and 328, the Cafeteria, Gym, Main Entrance Stairwell and 3rd floor North Corridor.⁷⁷ The concentrations from 78 samples ranged from 2.358ppm to 243,000ppm. The next step was pre-remediation air testing and wipe sampling. The locations of wipe sample included areas of high and low contact. 24 wipe samples indicated a range of undetectable (less than .100) to .716 $\mu\text{g}/100\text{cm}^2$.⁷⁸ During the air testing, windows were closed, but the ventilation system was on. The samples were taken near the middle of the rooms away from doors and windows. The results of the air tests showed from non-detect (less than 50.1 ng/m^3) to 1,460 ng/m^3 .⁷⁹

Each pilot study building was used to represent an alternative PCB remediation remedy. P.S. 178X/176 used patch and repair which consists of removing deteriorated and loose sections and filling the rest in with new caulk. PCB containing caulk in P.S. 309 was encapsulated with an epoxy and sealant. P.S. 199M used a complete removal of PCB caulk with manual tools and replacement with new caulk. The post-remedial results of the wipe samples presented all values .806 $\mu\text{g}/100\text{cm}^2$ or under.⁸⁰ The air sample results ranged from less than 49.6 ng/m^3 to 934 ng/m^3 which is still above the EPA suggested levels for that school age, 300 ng/m^3 and 100 ng/m^3 .

⁷⁵ TRC Engineers. "Interim Remedial Investigation Report for the New York City School Construction Authority Pilot Study to Address PCB Caulk in New York City School Buildings." (New York: June 15, 2011) viii.

⁷⁶ TRC "Interim Remedial Investigation Report for the New York City School Construction Authority Pilot Study to Address PCB Caulk in New York City School Buildings." 6

⁷⁷ "TRC initially surveyed and tested classrooms 112, 116, 120, 214, 312, 322, 336, two bathrooms (221 and 222), the Cafeteria, Gym, Main Entrance Stairwell, and 3rd Floor North Corridor to determine if PCB Caulk was present in the proposed Pilot Study Areas...No PCB Caulk was identified in any of the other bathrooms surveyed and tested. However, PCB Caulk was found in Classrooms 118, 202, 308, 316, 318, 320, and 328." TRC (2011): 7

⁷⁸ Used the American Society for Testing and Materials (ASTM) *Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling*. TRC (2011): 10

⁷⁹ USEPA Method TO-10A (Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using Low Volume Polyurethane Foam (PUF) Sampling followed by Gas Chromatographic/Multi-Detector Detection (GC/MD)). TRC (2011) 11

⁸⁰ One anomaly in the gym gave a result of 97.6 $\mu\text{g}/100\text{cm}^2$ which could not be replicated upon further testing. TRC (2011) 16

On the exterior of the buildings, soil and caulk were also tested. Soil "[S]amples were collected every 20 linear feet along the building face, in three rows, located approximately 0.5 feet, three feet and eight feet from the building. Samples were collected from zero to two inches below the ground surface."⁸¹ The soil results from 89 samples ranged from non-detect to 2.48ppm. Because some of the soil samples were higher than the 1ppm Federal standard, nearby exterior caulk was tested as well to identify if it was the source. Five of the seven samples contained concentrations of greater than 50ppm with the highest sample totaling 459,000ppm.⁸²

After the completion of testing, the building was ventilated for 24 hours with an HEPA filtered device. When samples were taken after the ventilation, the results still reached as high as 554 ng/m³ so the building and its heating and ventilation system were cleaned. The high values after cleaning finally triggered an evaluation of light ballasts as an additional PCB source. "Out of a total of 487 ballasts that were inspected, 334 (68.6%) had either leaking PCB ballasts or had evidence of historical leakage."⁸³ Even after the replacement of all fluorescent light fixtures, the gym and room 314 still had level above 300ng/m³. The next step was to encapsulate the PCB caulk with a silicone caulk directly over it. Results still initially came out between 49.3 ng/m³ and 599 ng/m³.⁸⁴ However, the gym was tested again one month, two months, and five months later showing results all under 300ng/m³.

During phase two of the project, from April through October 2011, the SCA completed additional caulk surveys, took more pre and post remedial air and wipe samples, removed and replaced PCB caulk, evaluated Best Management Practices, remediated soils, evaluated ventilation systems, and wrote a Remedial Investigation Report with an analysis and results.⁸⁵ When new caulk was retested, the results indicated PCB contamination. "These results suggest

⁸¹ TRC "Interim Remedial Investigation Report for the New York City School Construction Authority Pilot Study to Address PCB Caulk in New York City School Buildings." 18

⁸² TRC "Interim Remedial Investigation Report for the New York City School Construction Authority Pilot Study to Address PCB Caulk in New York City School Buildings." 20

⁸³ Some of the ballasts had results of approximately 1,000,000ppm or 100% with additional PCBs in the potting insulation. TRC (2011) 28

⁸⁴ TRC "Interim Remedial Investigation Report for the New York City School Construction Authority Pilot Study to Address PCB Caulk in New York City School Buildings." 29.

⁸⁵ TRC Engineers, Inc. "Final Remedial Investigation Report for the New York City School Construction Authority pilot Study to Address PCB Caulk in New York City School Buildings." x.

that removal and replacement of PCB caulk, without additional actions to isolate the underlying substrate prior to installing the new caulk, is of limited benefit as a remedial alternative.”⁸⁶ Yet, the long term monitoring did not show concentration above the guidance levels.

Conclusion

The pilot study including P.S.199M reveals the complexity of PCB contamination in a building. In this study, indoor caulk containing PCBs contributed minimally to the airborne PCB levels. “Despite the relative ineffectiveness of the various caulk remedial alternatives, as evidenced by the long term monitoring results, the majority of post-remediation air samples were found to be below the applicable guidance criteria. In addition, there was not a statistically significant change in airborne PCB concentrations between pre- and post-remedial air sample results, suggesting that PCB caulk is not a major contributor to indoor PCB air concentrations at the schools that were evaluated.”⁸⁷ The results of the testing show that the probable cause for high indoor air concentrations of PCBs was leaking light ballasts rather than caulk. “Removal and replacement of the PCB light ballasts and associated fixtures had the most pronounced effect in terms of lowering PCB levels in air in the three Pilot School Buildings...The major source of airborne PCB in these schools appears to have been leaking light fixture ballasts, rather than caulk.”⁸⁸ When abating in schools, light ballasts should, perhaps, be considered as a priority material for removal.

If PCB contaminated caulk is not a significant contributor to airborne PCB levels, this would allow for more flexibility when abating it from historic structures. However, one potential reason that PCB concentrations remain high after the removal of caulk is that the PCBs from the contaminated caulk had already seeped into the adjacent substrate. This could present a much more complex historic preservation challenge if concentrations remain above guidance levels even after alternate sources of PCBs, such as light ballasts, have been abated.

⁸⁶ TRC “Final Remedial Investigation Report for the New York City School Construction Authority pilot Study to Address PCB Caulk in New York City School Buildings.” xiii

⁸⁷ TRC “Final Remedial Investigation Report for the New York City School Construction Authority pilot Study to Address PCB Caulk in New York City School Buildings.” xiii

⁸⁸ TRC “Final Remedial Investigation Report for the New York City School Construction Authority pilot Study to Address PCB Caulk in New York City School Buildings.” xii

The preservation of P.S. 199M was not significantly affected by PCB abatement. The historic fabric on the exterior of P.S.199M was not impacted by the remediation. The old caulk was removed using the preferred method of hand tools and simply replaced with new caulk, which did not change the appearance of the façade. However, the PCB-free caulk that had been applied in 2008 showed concentrations greater than 50ppm. In just three years, PCBs migrated back into the caulk from the substrate. The problem has yet to be resolved completely, so the fate of the school remains unknown.

This case study presents another essential component to PCB abatement, public opinion. The New York public school system is faced with pressures from parents and politicians who want accurate information and safe schools. The current estimate of potential schools in New York City with PCB contamination is 1200.⁸⁹ Although the city may be unable to start abatement on all contaminated school due to budget constraints or lack of resources, using interim measures will protect students and may ease the worry parents have as well. Although the pilot study had varying results, increasing ventilation tends to decrease PCB concentrations in indoor spaces. For exterior sources, such as soil contamination, a layer of topsoil may be used to cover it.

The pilot study is by no means irrefutable on how PCBs migrate to the air or what danger they present in New York City schools, but it does offer a lot of new information. With so many variables the study has to be looked at with a critical eye. Many of the results were inconsistent from one building to the next, so there are many questions remain about PCBs, their properties, and potential sources.

⁸⁹ New York Lawyers for the Public Interest, (New York: April 4, 2013)

Case Study 2: MIT Westgate Cambridge, MA



Figure 6.2.1: Westgate Low-rise, MIT, Cambridge, MA

Photographed by Emily Sinitski, 2013

Introduction

In the 1940's, Massachusetts Institute of Technology (MIT) had to manage a new group of students: war veterans. Not only were these veterans heading back to school after the war, but for the first time a large percentage of the student population was married with families. MIT built temporary housing to accommodate the students, but quickly realized that a more permanent solution was needed.⁹⁰ In 1957 the temporary units began to be phased out, as plans for the permanent structures were solidified. The new Westgate low-rises were completed

⁹⁰ Curtis, John Anthony. "A Redevelopment of the Westgate sites, Massachusetts Institute of Technology, Cambridge." (May 25, 1953): 7

in 1963 and the high-rise in 1967 (See Figure 6.2.1 for low-rise image). The buildings' horizontality is emphasized by the elongated brick courses under the windows. These courses are interrupted with vertical concrete segments that mark where the entrances are located.

The abatement of polychlorinated biphenyls at Massachusetts Institute of Technology's Westgate complex started in 2006. At an August 10, 2006 meeting, the university stated that it found between .1-5ppm PCB concentrations in soil outside low rise buildings A, B, and C.⁹¹ Because the windows had all been replaced in the 1990's, the soil was thought to be the only location of PCBs around Westgate. The process of testing and abatement occurred over several years and included a variety of testing methods.

Summary of Results:

Soil samples were the first tested. Out of 55 soil samples, 33 contained less than 1ppm and only 3 were above 5ppm.⁹² The highest concentrations of PCBs occurred within 10 feet of the building and were abated by removing the old soil and replacing it with new topsoil.⁹³

During the Westgate renovations that began in 1992, all of the window caulk was removed and replaced with new PCB-free material. Samples of non-window caulk were taken from Westgate A, B, and C and found to have concentrations higher than the threshold, 50ppm. Although sampling was not required because no renovation work was planned and the caulk was in stable condition, once the voluntary test revealed elevated concentrations, it had to be abated.⁹⁴ The abatement was scheduled to begin on November 29th, 2006 on the southern wall of Westgate A, B, and C.⁹⁵

On May 14, 2007, additional samples were taken on the exterior of Westgate A, B, and C with drills and hand tools.⁹⁶ The residents were asked to shut their windows and doors. "After a meeting with representatives from the EPA on July 10, 2007, MIT is considering using a chemical

⁹¹ MIT "PCB Abatement Project: EHS Presentation" Westgate Town Hall. (August 10, 2006)

⁹² MIT "Information Sheet #1 MIT W85—Westgate." (August 10, 2006): 1

⁹³ MIT "Information Sheet #1 MIT W85—Westgate."

⁹⁴ MIT "Information Sheet #2 MIT W85—Westgate" (September 2006)

⁹⁵ MIT "Information Sheet #3 MIT W85—Westgate." (November 27, 2006)

⁹⁶ MIT "Information Sheet #4-MIT W85—Westgate." (May 10, 2007)

wash to remove residual PCBs found in the concrete and brick.”⁹⁷ The contractor Dec-Tam used the product CAPSUR for its pilot tests on horizontal and vertical surfaces. “Before the vertical concrete surfaces are washed, approximately 10 linear feet of caulk will be removed from various building joints (brick to concrete, etc). Approximately 15 bricks will be removed from the concrete/brick joint to test underneath for PCBs (See Figure 6.2.4). After these actions, the chemical wash pilot test will be performed, and new samples will be taken to determine the effectiveness at removing residual contamination.”⁹⁸ Ultimately, the pilot test method was not the final solution for the façade because of the structural concerns associated with removing so much material. The caulk was still removed, but a silicone encapsulation was used as an alternative to brick removal.

Conclusions:

Unlike Case Study One, marked differences appear between pre and post remediation of PCBs at Westgate. Primarily, the MIT Westgate complex PCB abatement involved the removal of PCB contaminated bricks (See Figure 6.2.3). Although this was not chosen as the final abatement procedure for this particular project, the approach, if used on historic buildings, may have a detrimental impact. Another risk to the historic integrity of the building is encapsulation. Figure 6.2.2 shows a Westgate low-rise prior to encapsulation. The original concrete is dark tan with a rough texture. Figure 6.2.3 pictures the low-rise after encapsulation. The coating is meant to match the color of the concrete to some degree, but is much lighter with a smoother finish. Encapsulation is only used under the windows which gives the façade a patchy appearance.

Although the encapsulation does not preserve the original appearance of the building, the university’s approach is noteworthy. MIT incorporated monitoring the concrete encapsulation into their maintenance plan. (See figures 6.2.3, 6.2.5, 6.2.6, and 6.2.7 for encapsulation). As it weathers it turns red, so the school knows it is time to apply a new coating. The school used this project as a way to develop a PCB abatement plan for the rest of the campus if necessary in the future.

⁹⁷ MIT “Information Sheet #5 MIT W85—Westgate.” (July 20, 2007).

⁹⁸ MIT “Information Sheet #5 MIT W85—Westgate.”

Because Westgate is a community of families, there is an added concern for the health and safety of the children. This is a unique case because the people living in the buildings are highly educated in the technology fields. After speaking with William VanSchalkwyk at MIT, he mentioned the understanding nature of the students and their families due to the transparency of the school. The work was explained and an open discussion actually led to an intellectual dialogue. Throughout the process, MIT kept the residents informed with meetings and notifications. Even though State and Federal Regulations mandate the removal of soil with a greater than 1-2ppm, the MIT staff reiterated that consumption of soil at these concentrations is no cause for alarm. MIT used the interim measure of covering the soil with a layer of fabric and mulch.⁹⁹



Figure 6.2.2: Westgate, Cambridge, MA
Photograph from Westgate Family Housing
Community Website Date Unknown:
web.mit.edu/westgate/newresidents.html



Figure 6.2.3: MIT Westgate
Cambridge, MA
Photographed by Emily Sinitski, 2013

⁹⁹ MIT "Information Sheet #1 MIT W85—Westgate." 2



Figure 6.2.4: Westgate Brick Removal
Cambridge, MA
Image Courtesy of MIT, 2007



Figure 6.2.5: Westgate Encapsulation Detail
Cambridge, MA
Photographed by Emily Sinitski, 2013



Figure 6.2.6: Westgate Encapsulation Detail
Cambridge, MA
Photographed by Emily Sinitski, 2013



Figure 6.2.7: Westgate Silicone Encapsulation Detail
Cambridge, MA
Image Courtesy of MIT, 2007

Case Study 3: University of Massachusetts, Amherst



Figure 6.3.1: Lederle Graduate Research Center, Amherst, MA

Photographed by Emily Sinitski, 2013

Introduction

The University of Massachusetts, Amherst initiated a survey to locate polychlorinated biphenyls on the Lederle Graduate Research Complex in 2006. Lederle was designed by architects Campbell, Aldrich, and Nulty. The complex includes Tower A, Tower B, Tower C, the low-rise, and the Conte National Center for Polymer Research building (See Figure 7.6). The three towers are each 17 stories tall. Tower A and the low-rise were completed in 1972, Tower B and C in 1974, and the Conte building in the 1990s.¹⁰⁰ The buildings are used as classroom space, laboratories, and a library. The Conte building, built after PCBs were banned by the Toxic Substances Control Act (TSCA), is used as a control.

¹⁰⁰ Environmental Health & Engineering, Inc. "Preliminary Report of Building-Related Polychlorinated biphenyls assessment Lederle Graduate Research Complex, University of Massachusetts"(October 12, 2006) : 5

The University hired the firm Environmental Health & Engineering, Inc. (EH&E) to complete the testing before beginning renovations to the structures that involved securing the concrete panels. Because UMass Amherst is a public university, the testing, results, plans, and written correspondence with the EPA are accessible through their website. A combination of air, soil, lab samples, concrete cores, and wipe samples were taken to determine the presence and concentration of PCBs. The complex was chosen as a case study because of the use of PCB-containing caulk adjacent to concrete panels on the exteriors of the buildings. Caulk in contact with concrete is one possible area of concern in the historic preservation field. The concrete may absorb the PCBs from the caulk and remain contaminated.

Summary of Results

All five buildings were tested for the presence of PCBs. The exterior caulk in Towers B and C ranged between less than 1.0 to 4.0ppm which is well below the 50ppm limit for non-liquid applications. It was deemed safe to proceed with work on these two buildings. The majority of the wipe samples from Tower A and the low-rise were below the maximum 10 micrograms per 100 square centimeters ($\mu\text{g}/100\text{cm}^2$) with the exception of one sample from a low-rise window ledge, which yielded $34\mu\text{g}/100\text{cm}^2$. Five additional ledges were tested with results varying from 2.0-27.6 $\mu\text{g}/100\text{cm}^2$. Air samples from Conte, Tower A, Tower B, and Tower C were below the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit of 1.0 microgram per cubic meter ($\mu\text{g}/\text{m}^3$). The low-rise however had inconsistent results. The north side ranged from .44 to .69 $\mu\text{g}/\text{m}^3$, but the south side had results just over 1.0 $\mu\text{g}/\text{m}^3$. Southern exposure deteriorates caulk more rapidly. EH&E retested the area after increasing ventilation and the range decreased to between .22 to .64 $\mu\text{g}/\text{m}^3$.¹⁰¹

Since the test from Towers B, C, and the Conte Building did not yield results above the federal standard of 50ppm for caulk, the analysis will focus on the remaining two properties, the low-rise and Tower A built in the same year. The positive results in from caulk samples led to core samples of concrete adjacent to the joint. Core samples were taken at various distances

¹⁰¹ Environmental Health & Engineering, Inc. "Preliminary Report of Building-Related Polychlorinated biphenyls assessment Lederle Graduate Research Complex, University of Massachusetts" 5

from the PCB-contaminated caulk. At a distance of .25 inches away, the samples ranged from 12-92ppm in the three locations. At one and a half inches, the results ranged from .8 to 2ppm. At three inches away the samples ranged from .4-1.9ppm. The closest range produced results classified as bulk remediation. Even the one and a half and three inch distances show the migration capability of PCBs in porous masonry.

Conclusions

Testing for PCBs can yield confusing and varying results depending on methods and locations of the tests. Although almost all of the wipe samples on the low-rise detected minimal PCB concentrations, one sample from a window ledge was above the allowable limit. This is where investigating documentation on the history of the building is important. Prior renovations and power-washing were determined to be the cause of the elevated PCB levels. It is important to confirm results with additional sampling especially in the presence of an outlier. The case study offers a wealth of information in terms of interpreting data. Although Tower A and the low-rise had PCB concentrations greater than the allowable 50ppm, the indoor air results were mostly below the recommended exposure limit. When the results were higher than $1.0 \mu\text{g}/\text{m}^3$, increased ventilation decreased the level to under $1.0 \mu\text{g}/\text{m}^3$. An indoor carpet tested positive for PCBs which may be the result of tracked-in particles or mastic that was used to hold carpets in place.

Some of the concrete cores closest to the caulk had concentrations high enough to be considered bulk waste (>50ppm). The core samples of concrete show that the migration of PCBs to the adjacent substrate can reach up to three inches away from the caulk. The school chose to encapsulate rather than remove any concrete. Similar to Case Study Two, the coating applied to the concrete alters the appearance of the façade. The rough textured concrete with varying colors seen in Figures 6.3.2 and 6.3.4 contrasts the uniform, smooth appearance in Figures 6.3.3 and 6.3.6. Even the image taken in 2005 (Figure 6.3.5) has the streaky character of poured concrete.

In addition to the physical damage that PCB remediation may cause, this project demonstrates a potential financial burden. Positive PCB tests result in additional testing. The

longer it takes to find the causes of elevated PCB concentrations the more expensive the project may be. Universities with many properties built between 1950-1980 could potentially have many abatement projects to complete.



Figure 6.3.2: Lederle Graduate Research Complex
Photographed by unknown, During Construction

Figure 6.3.3: Lederle Graduate Research Complex
Photographed by Emily Sinitski, 2013



Figure 6.3.4: Lederle Graduate Research Complex
Amherst, MA
Image Courtesy of UMass Library Archives (estimate 1966)

Figure 6.3.5: Lederle Graduate Research Complex, Amherst, MA
Photographed by Unknown, 2005
<http://www.umasswiki.com/wiki/File:Lgrt-panorama.jpg>

Figure 6.3.6: Lederle Graduate Research Complex
Amherst, MA
Photographed by Emily Sinitski, 2013

Chapter VII: Implications of Abatement for Historic Structures

From the case studies, a number of implications for historic structures have been identified. Although none of the case studies are listed on the National Register or are landmarked, the research conducted can be extrapolated to find relevant concerns associated with historic properties. Many of the implications compare to those of other building hazards such as lead or asbestos. Primarily, the logistical concerns of PCBs including cost, time, and safety will be discussed in the context of historic preservation projects. In addition, the destruction of structural, aesthetic, and architectural features during abatement will be evaluated.

Due to the current EPA regulations, PCB abatement projects are incredibly case specific. Although this thesis set out to evaluate PCB caulk adjacent to porous masonry, other sources of PCBs are presented in every case study and cannot be removed from the discussion entirely. Some of these additional sources were contaminated due to deteriorated caulk such as the soil while others like light ballasts or mastic contain their own source of PCBs. In terms of aesthetics, the exterior caulk will be the focus of this chapter.

Cost

The associated costs with PCB abatement manifest themselves through tests, personal protective equipment, and the disposal at proper facilities. The cost depends on many case by case factors including the size of the building, how much contaminated caulk is found, and the agreed upon abatement plan. Multiple rounds of testing using different methods increase the budget with each test. At MIT the removal of caulk cost greater than \$100 per linear foot for an overall cost of just about \$2 million dollars.¹⁰² Fortunately, PCBs have not been found in caulk in single family residences, so historic house museums with limited budgets will probably avoid the challenges of PCB caulk removal. All renovation and preservation construction projects cost money, but PCB abatement can cut into funds saved for more preservation-oriented projects. When non-profits or other institutions raise money for renovation projects, it is more challenging to get donations for a necessary abatement. Although the end result decreases the

¹⁰² VanSchalkwyk, William. "Managing PCB in our infrastructure." Massachusetts Institute of Technology, Cambridge, MA.

health risks for occupants, there is little physical evidence to display the improvements on the completed building.

The three case studies each contained multiple contaminated properties because the owners were universities and municipalities. School and governmental facilities are among the types of buildings most likely to encounter PCB abatement projects. In New York City, the school building pilot study commenced to create a protocol for all buildings in the city, so the expenses will continue long past the study's end. MIT now has a program in place if PCBs are found to help facilitate the testing and abatement.

Time

Time may also vary significantly on a case by case basis, but there are some factors that help determine just how long PCB abatement may take. When abating a building, the EPA has a checklist of criteria to meet in order to proceed in a specific fashion. Unfortunately, nearly all PCB projects do not fall under these criteria. When a project fails to meet these guidelines, a new, customized plan is required with EPA approval before the work can be completed. Not taking into consideration the time it takes to hire a consultant, test the site, and write a plan, getting a response from the EPA may take months. On top of that time, that proposed plan may need to be altered and re-submitted for approval. The process can greatly slow a project down.

Similar to cost, the time frame is dependent on the size, scope, and number of buildings. In all three examples, several rounds of testing before, during, and after abatement take time to process. At P.S. 199M when the air samples continued to be above the guidance levels for kindergarten and elementary students, additional methods were attempted until finally the levels were low enough. Prior to testing, it is difficult to estimate the time frame of completion.

Safety

Making a case for historic preservation in the midst of a safety concern presents a dilemma. There is an ethical and legal obligation to remove PCBs once they have been found at concentrations greater than 50ppm because of the potential health problems they may cause, but whether or not a real danger exists depends on the circumstances. The safety of young children is an especially pertinent topic because of the function of the buildings, one case study

is an elementary school and another is a family residence complex. Unfortunately, because PCBs are still in the process of being studied, the uncertainty often causes uneasiness, especially when children are involved. School systems in New York City in particular have parents and politicians, who know just enough about PCBs to demand testing and removal from all schools.

From the case studies, it seems unlikely that PCBs in exterior caulk alone, even after migrating to the adjacent masonry, produce dangerous concentration in indoor air. Without evidence disputing the EPA's guidance levels or limits, the regulations will likely remain the same as a precaution. PCB-containing caulk should continue to be carefully abated and encapsulated to remove the compounds from the environment using methods that compliment the historic character of a building.

Loss of Integrity

The use of PCB-contaminated caulk adjacent to porous masonry structures can have devastating implications for the historic fabric. With high concentrations of PCBs in caulk, migration to brick or concrete is common. The porous material often yields concentrations higher than the 50ppm bulk remediation standard. When concentrations are so high, removing the caulk alone does not negate the hazard as PCBs remain in the substrate.

The abatement process can negatively impact the façade of a building in several ways. A primary concern is the loss of original materials. Removing caulk is not a preservation concern because it is a sacrificial material that is expected to be replaced every 15-20 years. The method of removal, however, can have implications for a building's appearance. Hiring a contractor with professional preservation experience is customary for joint cutting on a historic building. When removing PCB caulk, the joints should be cut without disrupting the adjacent substrate. Power tools can damage the substrate creating a more choppy edge or larger joint that changes the appearance of the building. Hand tools remove the caulk with more control and less dust creation, although are more labor intensive to use. Simply removing the caulk does not always mitigate the PCB contamination when PCBs have migrated to the porous substrate next to it.

When the porous material has been contaminated, extra building material may have to be removed. "In many cases of caulk contaminated with PCBs at > 1,000ppm, several millimeters

of the adjoining concrete contained PCB contamination in a concentration range of several hundred to several thousand parts per million.”¹⁰³ In the pilot study at MIT, two courses of brick that showed high levels of PCBs were removed. On a historic building, removing original bricks and obtaining matching replacements is a challenge. Retaining the original brick is preferred. Because the amount of brick that would have had to be removed was so great, MIT worked to create a new solution. The porous substrate can often be remediated using alternative methods.

Encapsulation is an alternative method to removal. Although the brick or concrete may have high concentrations of PCBs, removing the caulk significantly decreases the PCB concentration on a building. The PCBs in the remaining substrate can be controlled by encapsulation. Encapsulation is preferable to removal of original material, but it still alters the appearance of the building. All three case studies employed encapsulation techniques with varying success. The facades of Westgate and Lederle were noticeably altered from encapsulation. Greater care could be taken to match the color so that encapsulation has minimal visual impact. When working on a historic building, minimally invasive techniques are preferable so that the repair can be reversed in the future. Encapsulating porous material is essentially irreversible.

¹⁰³ EPA “Abatement Step 2: Conduct Removal and Abatement Activities.”

Areas of Further Study:

Research on PCB contamination directly relating to landmarked buildings is essentially a non-existent. However, because finding well-documented case studies of PCB abatement is challenging due to owner sensitivity of their contamination issues, examples almost certainly exist. An evaluation of buildings listed to the National Register that have undergone PCB abatement would help focus the general abatement plan for historic structures faced with similar problems. The three case study buildings in this thesis were constructed between the 1950's and 1970's, but PCBs can affect any building built before 1978. It would be worthwhile to see how renovation projects are affected by PCBs.

In addition to understanding the risks associated with PCBs, it is also important to bring a critical eye to the subject. Approaching a PCB contamination project on a historic building thoughtfully is important. Not all environmental scientists agree on the level of risk associated with exposure to PCBs or the current PCB abatement policies. In his paper "The public health implications of polychlorinated biphenyls (PCBs) in the environment," Gilbert Ross disputes health and environmental concerns associated with PCBs. He suggests that, "the fact that levels of PCB exposure have declined in all media strongly suggests that any theoretical risk to humans from such exposures has decreased as well."¹⁰⁴ He also notes that, "while there are studies that have alleged human effects from PCB exposure, the database is inconsistent in terms both of identifying a consistent toxicological endpoint and of providing studies in which PCBs were the only chemical under evaluation."¹⁰⁵ He elaborates about why PCBs may not be as hazardous as often described. If PCBs are not as harmful to humans and the environment as previously thought, their presence on historic structures may not require abatement or alteration to the original fabric.

PCB abatement is impacting building types that are often already difficult to preserve. Schools built during this time are rapidly disappearing because the programming inside does not coincide with present day educational theories. It would helpful to survey school buildings

¹⁰⁴ Gilbert Ross, "The public health implications of polychlorinated biphenyls (PCBs) in the environment." 277

¹⁰⁵ Gilbert Ross, "The public health implications of polychlorinated biphenyls (PCBs) in the environment." 279

built from 1950 to 1980 then see what percentages are faced with PCB contamination. Will PCB abatement affect the preservation of an already fragile building type?

New research on PCBs is completed every year. One promising system is being developed by the National Aeronautics and Space Administration (NASA). The Activated Metal Treatment System (AMTS) is intended to remove PCBs from paint.¹⁰⁶ The method is completed in situ. Currently, the system is only effective for up to three paint coats at a concentration as high as 700ppm, but with increased research and development, it may become a method for PCB removal from caulk as well.

Much of the research that would aid in the understanding of PCBs on historic masonry structures has yet to come. Some of these studies are out of the scope of knowledge of preservationists. An open dialogue should continue with environmentalists to stay up to date on recent discoveries. Pilot studies similar to that in New York are a good start to understanding PCB caulk and its risks, but more studies could field valuable results. Because the topic is still new, creating a plan now could help save many historic buildings in the future. It is my hope that through this discussion and proposed plan, historic preservationists will have a starting point for an intellectual conversation about PCB abatement in historic buildings.

¹⁰⁶ National Aeronautics and Space Administration, "Activated Metal Treatment System (AMTS) for Paints." Last Updated August 30, 2010.

Conclusions and Recommendations

The use of Polychlorinated Biphenyls in building applications pertaining to historic structures is vast, particularly in the Northeast, Midwest, and West. The contamination affects buildings of historic importance and many that are approaching the National Register's 50 year mark. The historic preservation community would benefit from a guide on PCBs and how to manage them in a historic structure. Using the preservation techniques used for lead paint and asbestos and the EPA's abatement steps, I have created a procedure for the abatement of PCB containing caulk on historic masonry structures.

- I. Identify the historical significance of the building and architectural character of its features and finishes;¹⁰⁷
- II. Undertake a risk assessment to determine the hazards from polychlorinated biphenyls;¹⁰⁸
- III. Submit a proposal to the EPA and engage temporary remediation techniques;
- IV. Evaluate the options for PCB hazard control in the context of historic preservation standards;¹⁰⁹

I. Identifying the historical significance is important for any preservation project, but in the presence of a toxin it is essential for deciding which aspects of the building to prioritize. "PCB-containing caulk typically has the highest PCB concentrations and will be given a higher priority for removal over other building materials. Masonry, wood, brick, and other building materials contaminated with PCBs typically contain lower concentrations of PCBs. Thus, these PCB-contaminated materials typically pose a lower potential for exposure than caulk and should be dealt with accordingly."¹¹⁰ When removing the risk, the highest concentration should be prioritized, although it is important to take into consideration other factors such as how the

¹⁰⁷ U.S. General Services Administration. "Historic Preservation-Technical Procedures: Procedures for Removing Asbestos-Containing Materials."

¹⁰⁸ U.S. General Services Administration. "Historic Preservation-Technical Procedures: Procedures for Removing Asbestos-Containing Materials."

¹⁰⁹ Adapted from Park and Hicks p. 3

¹¹⁰ EPA "Abatement Step 1: Prepare an Abatement Strategy."

spaces are used. At this time, the buildings should be photographed and documented, before alterations are made.

II. Undertaking a risk assessment is another opportunity to prioritize removal. If the building was constructed or renovated between 1950 and 1978, PCB contamination is possible. Look for elements known to contain PCBs, especially caulk or light ballasts. If PCBs are suspected in the building, hire an outside environmental consulting firm with PCB testing experience to collect air samples.¹¹¹ Testing for PCBs requires a trained eye and safety precautions, so must be done by a professional. Begin with air sampling to gauge human exposure to PCBs in the space. If the test comes back positive, wipe and bulk samples can supplement this data by identifying the source. No set number of samples is required from a building, but a representative amount would include samples in several location. Each sample should be large enough to create three subsamples to replicate the results for comparison.¹¹²

III. Working on a proposal for the EPA should commence immediately to expedite the process. While more permanent solutions may take some time to formulate, immediate measures can be taken to reduce PCB concentrations. Interim measures are general low-cost methods that can be completed in-house if necessary. The area should be vacuumed with a HEPA filter and cleaned thoroughly. Keeping the windows open to ventilate the space generally lowers the indoor air levels. If the ducts can be cleaned, this will eliminate another potential source. If levels are very high, temporarily change the use of the space if possible so that fewer people are in the contaminated regions.

IV. Finally evaluating PCB abatement in the context of historic preservation standards will help reduce damage to the historic fabric. The Secretary of the Interior Standards defines preservation as "the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property."¹¹³ Certain abatement methods are more compatible to these goals. When possible, hand tools should be selected over machines tools

¹¹¹ See chart below for list of tests

¹¹² TRC Engineers, Inc. "Final Remedial Investigation Report for the New York City School Construction Authority pilot Study to Address PCB Caulk in New York City School Buildings." Appendix D.

¹¹³ National Park Service, "Preservation as a Treatment."

to cut the joints. Loss of PCB caulk will rarely be a concern, but when porous masonry is contaminated, additional abatement plans may be considered. Whenever possible, masonry should be encapsulated as opposed to removed. Use test mock-ups to select a color for the coating that closely matches the original material. Encapsulation still has the potential to significantly alter the appearance of a building so should only be selected if it “will match the old [material] in design, color, and texture.”¹¹⁴

The suggestions are basic but can act as a starting point for PCB abatement in historic building.

Sample Location	Test Type	Sample Size	Threshold Level	When/Where to Use the Test	Cost Per Sample
Surface	ASTM D666-10 "Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling"	100cm ²	10µg/100cm ²	°Non-porous surface °Unknown PCB presence	\$100
Caulk	ASTM D6160-98(2008) "Standard Test Method for Determination of Polychlorinated Biphenyls (PCBs) in Waste Materials by Gas Chromatography"	3mL	50ppm	°Unknown PCB presence & concentration °Deteriorating caulk °Old but flexible Caulk	\$100
Soil	EPA Method 680: Determination of Pesticides and PCBs in Water and Soil/Sediment by Gas Chromatography/Mass Spectrometry	3mL	1ppm	°Soil adjacent to building containing PCB caulk °After a past removal of PCB Caulk	\$100
Air	ASTM: D4861-11 "Standard Practice for Sampling and Selection of Analytical Techniques for Pesticides and Polychlorinated Biphenyls in Air" ^{**}	4-24 hours	1µg/m3 Varies- depending on age ^{**}	°Before/During/After PCB removal °When human exposure is occurring	\$550
Substrate	ASTM D6160-98(2008) "Standard Test Method for Determination of Polychlorinated Biphenyls (PCBs) in Waste Materials by Gas	3mL	Varies	°Adjacent to PCB caulk °Adjacent to PCB caulk that has since been removed	\$100

*EPA test: Compendium Method TO-4A Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using High Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/Multi-Detector Detection (GC/MD)

*EPA test: Compendium Method TO-10A Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using Low Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/Multi-Detector Detection (GC/MD)

**Exposure levels are guidance only, this number is taken from the National Institute for Occupational Safety and Health (NIOSH)

¹¹⁴ National Park Service, "Preservation as a Treatment."

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