PCBs in Caulk Project: Estimated Stock in Currently Standing Buildings in a San Francisco Bay Study Area and Releases to Stormwater during Renovation and Demolition

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Study Questions

1. Do Bay Area buildings have PCB concentrations in caulk similar to those reported in other surveys?

2. How can we determine the standing mass of PCBs in caulk in Bay Area buildings? What are the uncertainties in the estimate?

3. Are available data sufficient for generating an estimate of PCB loads associated with building demolition and renovation to runoff? What are the uncertainties in the estimate?

4. Is the estimated PCB mass released from building demo/reno larger or smaller than other PCB sources?

5. What are the key recommendations from this pilot investigation?

Project Elements

1. **Field assessment**
   - Analyzed PCBs in 25 caulk samples from SF Bay study area buildings
   - Compared results to other locations
   - Used to estimate total PCB mass in study area buildings

2. **GIS exercise**
   - Estimated PCB stock in currently standing buildings in study area

3. **Spreadsheet evaluation**
   - Estimated PCB mass released to runoff during demo/reno using available information
   - Compared mass to other PCB sources

4. **Identified data gaps and recommended next steps**

#1. Field Assessment -- Methods

Sample Collection

- 29 exterior caulk samples from 10 Bay Area buildings
- 1-7 samples per building
- Max 1 sample per caulk function/location on each building
- Targeted 1950s-1980s buildings known/suspected to contain original caulk
- Blind sampling approach
  - Did not collect building location information
  - Recorded decade of construction, construction type

Field Assessment -- Methods

Analyzed 25 samples

- GC-MS (44 congeners)
- Portable XRF (chlorine)

Table 2. Summary of results from this study and previous surveys of PCBs in caulk in buildings.

	San Francisco Bay Area[a]	Greater Boston Area[b]	Toronto[c]	Switzerland[d]
Sample size (n)	25	24	95	1348
Building Use Types	Mixed	Institutional	Commercial, industrial, residential, infrastructure	Institutional
Construction Types	Concrete, wood, masonry, unknown	Concrete, masonry	Concrete, brick, other	Concrete
PCB detection frequency	88%	54%	14% (27% not including residential)	48%
PCB detection frequency for samples >50 ppm	40%	33%	14% (27% not including residential)	42%
Range of PCB concentrations detected in caulk samples (ppm)	1-220,000	70-36,000	570-82,000	>20-550,000
Method detection limits (ppm)	≥25	0.5	50	20

[a]This study; [b]Herrick et al. 2004; [c]Robson et al. 2010; [d]Kohler et al. 2005

Use Similar Among Locations?

- For samples >50 ppm, median (9,600 ppm) comparable to Boston, Toronto (~8,000 ppm)
- % >10,000 ppm (20%) comparable to Boston (9%), Toronto (10%), Switz (20%)
- Max concentration higher than Boston, Toronto
- Aroclor 1254

Table 1. PCB concentrations in caulk from San Francisco Bay Area buildings.

Building Construction Year	Building Construction Type*	Caulk Location on Building	PCB concentration (ppm)
1950s	PC2	Between concrete	220,000
1950s	PC2	Between concrete	198,000
1950s	PC2	Between metal window frame and concrete	146,000
1960s	W2	Between glass and window frame	12,500
1950s	PC2	Between concrete	11,500
1950s	PC2	Around metal window frame	7,630
1950s	PC2	Between glass and metal window frame	3,600
1960s	C2	Between window glass and window frame	89
1980s	RM	Unknown	87
1970s	W2	Between wood and wood	60
1960s	C2	Between window glass and window frame	48
1950s	W1	Between glass and metal window frame	15
Unknown	Unknown	Around window frame	15
1970s	W2	Between glass and window frame	11
1970s	W2	Between window frame and wood	10
1970s	W2	Around doorframe	8
1950s	W1	Around doorframe	6
1950s	W1	Around doorframe	5
1950s	W1	Between glass and window frame	3
1950s	W1	Between metal window frame and concrete	2
1960s	PC1	Between concrete	2
1950s	W1	Between wood window frame and wood	1
1950s	W1	Between wood and concrete	0
1950s	W1	Between wood and wood	0
1960s	RM	Between glass and window frame	0

*Construction codes: PC1=Precast/tilt-up concrete shear-wall; PC2=Pre-cast concrete frame; C2=Concrete shear-wall; W1=Light wood-frame residential and commercial smaller than or equal to 5,000 square feet; W2=Light wood-frame larger than 5,000 square feet; RM=Reinforced masonry

Many Samples <50 ppm

- 48% of samples <50 ppm
- Median 32 ppm (all samples)
- Volatilization?
- Secondary contamination from other PCB-containing materials?
- PCB contaminated equipment?

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Field Assessment – Temporal Distribution

Table 3. Temporal distribution of PCB concentrations in caulk samples from San Francisco Bay Area buildings.

Construction Year	# samples	# <MDL	# >MDL-50 ppm	# 50-10,000 ppm	# >10,000 ppm	% >50 ppm
1950s	14	2	6	2	4	43
1960s	5	1	2	1	1	40
1970s	4	0	3	1	0	25
1980s	1	0	0	1	0	100
Unknown	1	0	1	0	0	0
Total #	25	3 (12%)	12 (48%)	5 (20%)	5 (20%)	

- PCBs in buildings constructed 1950s-1980s
- Samples > 1% constructed in 1950s, 1960s (but small sample size)
- Highest concentrations in 1950s buildings

PCBs and Caulk Location

- Samples from between concrete blocks, window frames on concrete buildings contained highest concentrations
- Low concentrations in wood frame buildings

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Use of XRF to Predict PCBs?

High likelihood of false positives

- When XRF detected Cl, no/very low PCBs
- Likely presence of non-PCB Cl in caulk
- Could not assess in this study (PCBs detected in most samples, inconsistent results)

Useful for identifying caulk that does not contain PCBs > 1%?

- XRF detected Cl when PCBs % levels, but not when PCBs <0.1%
- XRF Cl not useful for predicting PCB concentration

Field Assessment -- Conclusions

- PCBs present in caulk in SF Bay Area buildings built in 1950s, 1960s, 1970s, 1980s
- PCB concentrations comparable to other locations
- Small sample size leaves uncertainty regarding prevalence in buildings and concentration range

#2. GIS Exercise – PCB Stock Estimate

First step in determining importance as a potential source to environment

Goal:
Estimate the PCB mass in caulk in currently standing, commercial, industrial buildings constructed between 1950 and 1980 in the San Francisco Bay study area

Use to:

- Estimate PCB mass released to urban runoff during the renovation and demolition of these buildings
- Inform decisions regarding potential management of building caulk

GIS Exercise – PCB Stock Estimate

Actual building inventory databases not available

GIS Approach

- Estimate number, area, volume of currently standing buildings in the study area built during era of PCB use
- Based on historical, modern imagery and land use data
- Characterization of buildings in randomly selected samples in area
- Scale up to estimate total building counts, areas

Assumptions from previous studies applied to GIS results to calculate estimate of total PCB mass

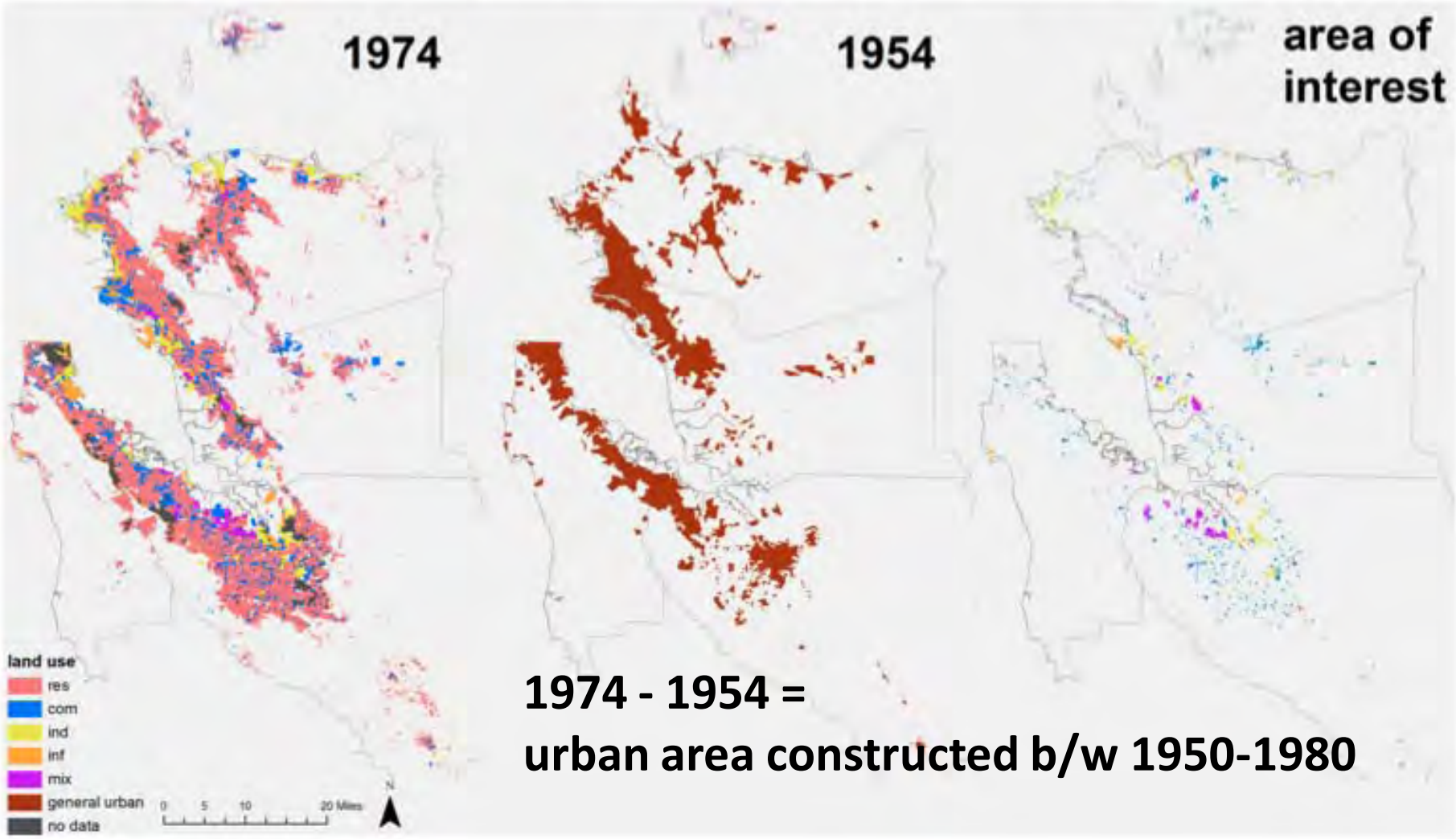
San Francisco Bay Study Area

- Area covered by the current Phase I municipal regional stormwater permit (MRP): Alameda, Contra Costa, Santa Clara, and San Mateo Counties, and the cities of Fairfield, Suisun, and Vallejo
- The Counties of San Francisco, Marin, Sonoma, Napa, and most of Solano are excluded from this area

PCB Stock Estimate – GIS Methods

1. Identify urban area constructed from 1950-1980
    - Land use from 1954 erased from 1974 (USGS, ABAG data)
    - Only commercial, industrial, infrastructure, mixed comm/ind land use from 1954-1974 was retained (no residential)
    - 'Area of interest' (AOI)

Figure 2. Historical Land Use Maps Used to Create the Study Area of Interest (AOI). Note that the area of interest excludes residential land use because it is currently understood that PCBs were not commonly added to caulk in residential structures.



PCB Stock Estimate – GIS Methods

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    - Land use from 1954 erased from 1974 (USGS, ABAG data)
    - Only commercial, industrial, infrastructure, mixed comm/ind land use from 1954-1974 was retained (no residential)
    - 'Area of interest' (AOI)

2. Quantify area of buildings that are still standing today
    - Create subset of 2005 land use data (ABAG); remove roads, lots, yards, rails; keep transportation and utility-related buildings
    - Keep only overlapping areas between AOI and 2005 land use (focus area)

PCB Stock Estimate – GIS Methods

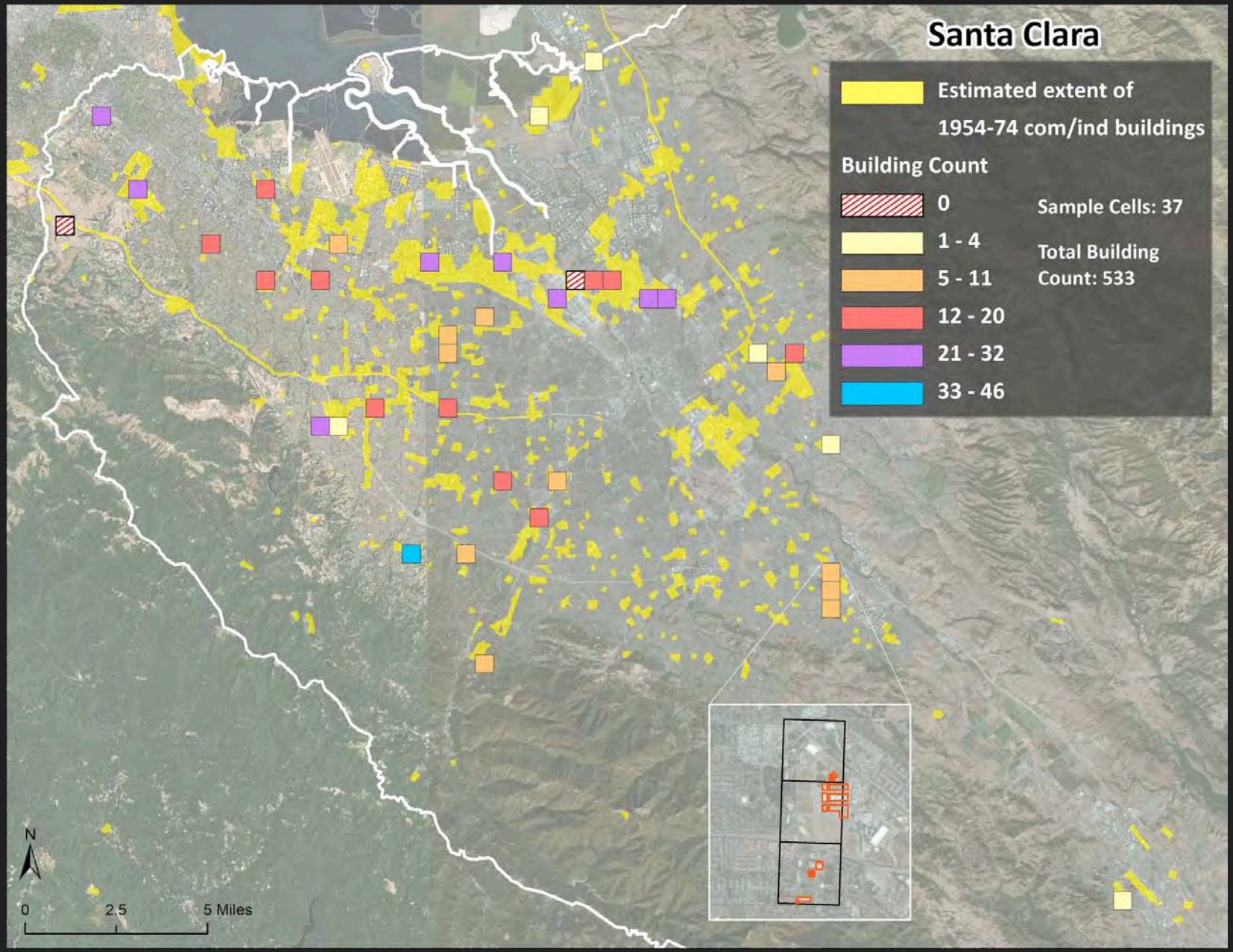
Building area footprints and # buildings in randomly selected sample cells were scaled up to estimate total area and # in the study area

Sample cells

- Grid of 0.25 mi^2 cells in focus area
- 100 cells analyzed; # analyzed in each MRP county proportional to focus area within each county

Building #/area footprints in each random sample cell

- Digitized buildings that were present in both 1982 and 2009 imagery, and that overlapped with focus area
- Quantified # of buildings per cell, building area by land use type
- Scaled up building #, area per MRP county


Santa Clara
Estimated extent of
1954-74 com/ind buildings
Building Count
0
1 - 4
5 - 11
12 - 20
21 - 32
33 - 46
Sample Cells: 37
Total Building
Count: 533
N
0
2.5
5 Miles

PCB Stock Estimate – GIS methods

Key Considerations

- 1954, 1974 only historical urban data available – buildings constructed before and after that may have contained PCB caulk were not accounted for
- Pre-1954 buildings renovated with PCB caulk between 1950-1980 not included – mass may be underestimated

Table 4. Factors used to estimate the PCB mass in caulk in San Francisco Bay study area buildings

Factor		Source
Height of one building story (ft)	10.3	Serdar et al. 2011; not standardized
Average # of stories in study area buildings	1.46	This study, Section 3.2.1
Mass caulk per volume building (g/m^3)	55	Robson et al. 2010; estimate from building contractor in Toronto
% of buildings with PCB > 50 ppm in caulk (i.e., detection frequency)		Based on detection frequencies in this study, Boston (Herrick et al. 2004), Toronto (Robson et al. 2010), and Switzerland (Kohler et al. 2005).
Low	22	
Medium	36	
High	46	
PCB concentration in caulk (ppm)		25th, 50th, and 75th percentiles of the concentration distribution of this study, Boston (Herrick et al. 2004), and Toronto (Robson et al. 2010). Only samples with PCB > 50 ppm collected from buildings built between 1950-1980 were considered.
Low	950	
Medium	7,990	
High	27,300	

PCB Stock Estimate – PCB Mass Calculations

Total # buildings w/PCB caulk = total # buildings X PCB detection frequency

Total volume of buildings w/PCB caulk =
total # buildings w/PCB caulk X Avg building area X Avg building height

Total PCB caulk mass in buildings =
Total volume of buildings w/PCB caulk X caulk density in buildings X PCB caulk concentration

PCB Mass in SF Bay Study Area

Table 6. Estimates of PCB mass in caulk in the San Francisco Bay study area buildings

	PCB mass in caulk in study area buildings (kg)	Average PCB mass in caulk per building (kg)
Low estimate	767	0.6
Medium estimate	10,500	4.7
High estimate	46,000	16

- Similar to estimate for Toronto (13,000 kg); 1980 populations comparable
- Lower than Puget Sound watershed (59,000 kg)
- Lower than Switzerland (50,000-150,000 kg)

PCB Mass in Caulk Compared to Other Sources

Table 7. Comparison of PCB mass in caulk to estimates of PCB mass in other sources and current uses (McKee et al., 2006).

	PCBs in caulk in buildings[1] (kg)	Transformers or large capacitors still in-use[2] (kg)	Small capacitors (fluorescent light ballasts) still in use	Shredder waste (kg/y)[3]
Low estimate	767	-	?	140
Medium estimate	10,500	197,000	?	1,300
High estimate	46,000	-	?	2,440

[1] The present study. [2]USEPA voluntary database. Note that all the entries in this database happen to be within the focus study area of this current report (Counties of Alameda, Contra Costa, Santa Clara, San Mateo, and the cities of Fairfield, Suisun City, and Vallejo). [3]For the nine county Bay Area excluding City and County of San Francisco.

- Mass in caulk significant (others for 9 County Bay Area)

Table 8. Elements of uncertainty in the PCB mass estimate[1].

Element	Likely to bias estimate high or low?	Likelihood of improvement	Ease of efforts to address in short-term
Imperfect ABAG 2005 land use layer	Unknown bias	High likelihood of an updated version	Easy; improvement for this application unknown
No data available to validate the caulk mass per building volume assumption (55g /m^3)	Unknown bias	High	Moderately easy with local survey
Limited information on the use of PCBs in caulk in residential buildings	Low	High	Moderately easy with residential building survey
No data to validate total building counts in study area	Unknown bias	High	Moderate with an increased number of random grid cells included in GIS analysis
PCB mass in buildings containing <50 ppm in caulk	Low	Moderate	Difficult; more sensitive lab method may be needed

[1] The table indicates whether the uncertainty element is likely to bias the estimate high or low, the likelihood of improving or increasing confidence in the estimate (high, medium, or low), and the ease of conducting these efforts or acquiring additional data to address this element in the short-term (high, medium, or low).

Recommendations for Improving PCB Stock Estimate

- Validate # of buildings constructed during era of PCB use in caulk
  - Municipal database aggregation
  - Increase # random cells analyzed in GIS method
- Validate estimates for prevalence of PCBs in buildings (different building types, locations; PCB concentration distribution)
  - Systematic collection of caulk from larger # of buildings; target specific building types, locations on buildings
- Validate estimate for avg mass caulk per volume building (55 g/m^3)
  - Info from local building contractors

#3. PCB Mass Released to Runoff

Goals:

- Estimate the PCB mass released to urban runoff during the renovation and demolition of these buildings using current practices (i.e. prior to any PCB in caulk BMP implementation)

- Compare the estimated PCB mass released to stormwater from building renovation and demolition to other PCB sources in the study area

- Identify data gaps/uncertainties

- Recommend next steps

PCB Mass Released to Runoff

What This Estimate Does Not Include:

- Emissions/releases to runoff as a result of natural processes (e.g., weathering/erosion of caulk; volatilization or leaching of PCB into air/water)

PCB Mass Released to Runoff

Methods

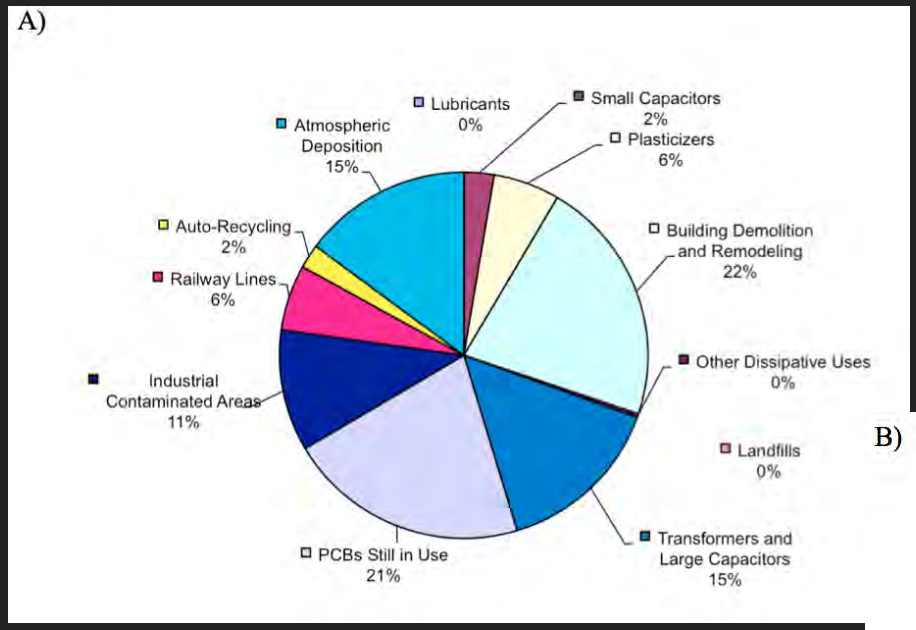
- Applied similar assumptions used in stock estimate, demo/reno records
- Based on single study of releases during PCB caulk replacement using decontamination procedures (Jansson et al 2000)
- Only releases during actual demo/reno processes considered
- Losses due to caulk scraps/rubble dispersed on- or offsite following procedures were not considered
- Considerable uncertainty in the estimate

PCB Mass Released to Runoff

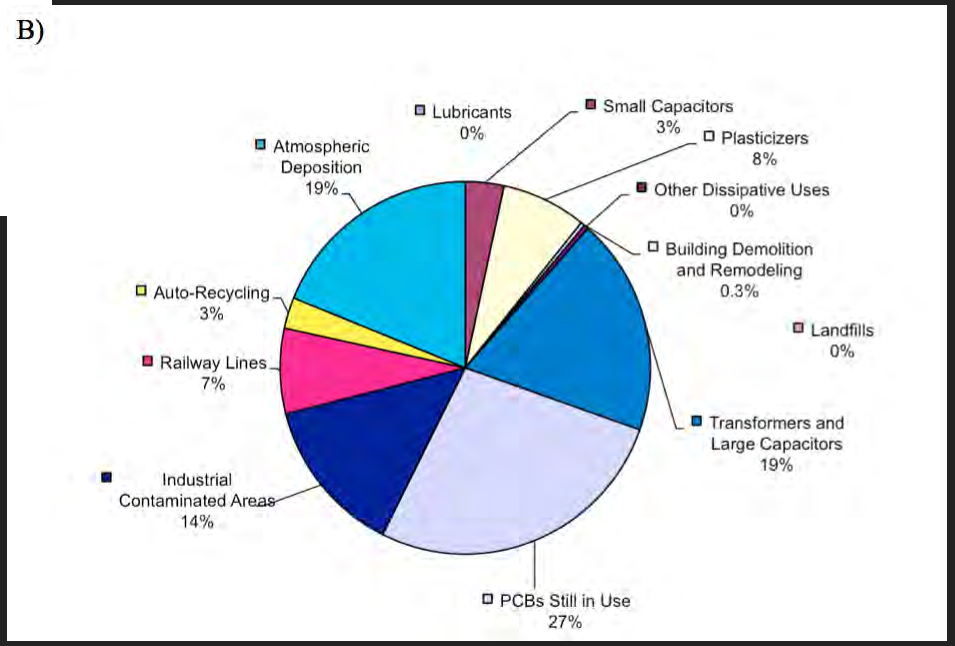
Table 10. Estimated annual PCB mass released from caulk to stormwater during building demolition and renovation activities in the San Francisco Bay study area (kg/yr)

	PCB mass from demolitions	PCB mass from renovations	Total PCB mass
Low estimate	0.0004	0.0004	0.0008
Medium estimate	0.02	0.02	0.04
High estimate	0.22	0.39	0.6

Estimates of PCB Mass from Various Sources Entering Stormwater in the Bay Area



McKee et al 2006



McKee et al 2006 including estimate for supply from caulk from this study

Uncertainties in Runoff Estimate

Table 11. Elements of uncertainty in the PCB mass release to stormwater estimate[1].

Element	Likely to bias estimate high or low?	Likelihood of improvement	Ease of efforts to address in short-term
Number of unpermitted building renovations in the Bay Area	Low	Low	Difficult without improved enforcement
PCB mass in caulk released to the environment during building renovations and demolitions	Low	Moderate	Difficult - measurable but expensive
Residual PCB in caulk on site after renovations and demolitions	Low	Low	Difficult – data anecdotal unless routinely collected

[1] The table indicates whether the uncertainty element is likely to bias the estimate high or low, the likelihood of improving or increasing confidence in the estimate (high, medium, or low), and the ease of conducting these efforts or acquiring additional data to address this element in the short-term (high, medium, or low).

Recommendations for Improving Runoff Estimate

- Validate # of demolitions/renovations in the Bay Area by building type, construction year
  - Consulting local contractors?
- Validate mass PCB released from caulk during demo/reno
  - Pilot studies of actual demo/reno -- quantify losses to air/soil, collect samples to evaluate BMP effectiveness
- Conduct study to estimate PCBs entering runoff from residual caulk scraps
  - Fraction remaining on-site? Particle size distribution? Fraction remaining w/debris, ground up for re-use? Fraction of these exposed to runoff? Fraction removed by construction stormwater BMPs?

Study Questions Revisited

1. Do Bay Area buildings have PCB concentrations in caulk similar to those reported in other surveys?
   - PCB caulk present in SF Bay Area buildings built in 1950s, 1960s, 1970s, 1980s (<MDL – 220,000 ppm)
   - Concentrations comparable to other locations

2. How can we determine the standing mass of PCBs in caulk in Bay Area buildings? What are the uncertainties in the estimate?
   - ~10,000 kg PCB (800-46,000 kg) in caulk in study area buildings
   - GIS approach seems reasonable
   - High uncertainty in estimate

Study Questions Revisited

3. Are available data sufficient for generating an estimate of PCB loads associated with building demolition and renovation to runoff? What are the uncertainties in the estimate?

- No – data limited to one unpublished study of limited use
- No data to quantify residual PCBs in caulk scraps

4. Is the estimated PCB mass released from building demo/reno larger or smaller than other PCB sources?

- Current estimate (0.3%) < previous estimate (22%)
- Much < in-use PCB (27%), transformers/capacitors (19%), atmos. deposition (19%), contaminated industrial areas (14%), others

5. What are the key recommendations from this pilot investigation?

- More thorough GIS evaluation?
- Demo/reno runoff case study?

Buildings in the Study Area Built 1950-1980

Table 5. Estimated number of currently standing buildings in the study area built during the era of PCB use in caulk[1]

Land Use	Alameda	Contra Costa	Fairfield	San Mateo	Santa Clara	Vallejo	Total Land Use
Commercial	988±40	942±49	50	288±27	1,932±44	5	4,204
Industrial	630±34	193±11	0	17	1,017±39	0	1,858
Infrastructure	27	58±34	5	29	17	0	136
Mixed	4	0	0	35±52	51±15	0	90
Total # of buildings	1,649±37	1,193±42	55	369±29	3,017±42	5	6,288
Total area of municipality (mi^2)	743	743	30	453	1,297	33	
# Buildings per mi^2	2.2	1.6	1.8	0.8	2.3	0.2	

[1] Additional significant digits were maintained for the purpose of propagating calculations but do not represent the degree of certainty.