Use of the Superfund/Elutriator Method to Determine Asbestos Structure Concentrations in Beach Sand

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Purpose of Study

Problem statement: ACM found washed onto Illinois Beach State Park (IBSP) beaches since 1997.

IBSP needs beach nourishment sand to prevent erosion from damaging the Park.

Apparent sources of ACM related to infrastructure from previous development in & around North Unit of the Park & previous sources of sand for beach nourishment, some of which were near former Johns-Manville property.
Purpose of Study

To answer the question: Are 2 lake-bottom potential sand sources appropriate?

• Phase 1: To make a statistical comparison of asbestos structure concentrations in sand sources proposed for beach nourishment, IBSP beaches, and background locations
• Phase 2: If beach nourishment results significantly greater than background levels, follow up with an assessment of risk

This presentation presents sampling and analytical methods & results used for Phase 1
Illinois Beach State Park (IBSP) Background

• **General**
  - 4,160 acres - 6.5 miles long on Lake Michigan shoreline
  - Approximately 1.2-1.4 million visitors per year 2003-04

• **Geology**
  - Shoreline undergoes continual erosion (net southward) along most of the shoreline (about 10 ft/yr)
  - 80,000-100,000 cubic yards of sand required per year for beach nourishment
North Unit Erosion & Feeder Beach

Photograph in Waukegan News-Sun, July 21, 1977

Photograph by Illinois State Geological Survey, April, 1973

Photograph by M. Chrzastowski, May, 2000

ruins of submerged shore protection for former housing

feeder beach
Study Design - Locations

• Target areas:
  – Illinois Beach State Park, North Unit
  – Illinois Beach State Park, South Unit
  – Waukegan Harbor Approach Channel lake-bottom sand
  – North Point Marina lake-bottom sand

• Background areas:
  – Grant Park Beach (South Milwaukee), WI
  – Highland Park Beach, Highland Park, IL
  – Oak Street Beach, Chicago, IL

Background areas chosen because no known beach nourishment, believed to be part of same sand littoral drift
Sampling locations at Illinois Beach State Park and entrances to North Point Marina and Waukegan Harbor.
Study Rationale

• ACM could release fibers through slow degradation
• Fiber transport dynamics in water unknown, presumed well-mixed
• Traditional bulk sampling and analytical methods found minimal or non-detectable asbestos in beach & lake-bottom sand
• Air sampling not possible for lake-bottom sand
• Fiber (structure) concentration in sand could quantify low-level contamination if low analytical limits
• Dominant wave action causes net transport of sand north to south
Environmental fate and transport of asbestos

- Persistent in environment
- Settles out of air and water slowly into soil and sediment
- Chrysotile may degrade in water and acidic environments
- Undergoes minimal or no photolysis, volatilization, or biotransformation
- Some chemical speciation and sorption occurs
- Fate poorly understood

Presumed mechanisms of transport in environment: Air deposition, storm water runoff, water, other?
2 relevant studies on presence of asbestos in environment

• Street dust or soil (Castro Valley, CA, pop 57,300): Total fibers of all lengths, expressed as concentration of fibers per gram of material (street dust or soil):
  – Range: $55 \times 10^6 - 1,900 \times 10^6$ f/gram. 2 creek sediment samples $39 \times 10^6 - 230 \times 10^6$ f/gram. Median fiber lengths = 0.7-1.7 $\mu$m in length, 0-30% of the fibers > 2.49 $\mu$m in length. <10% of all samples amphiboles, about 3% of street surface samples amphiboles (Pitt, Robert. Asbestos as an urban area pollutant, Water Pollut. Control Fed., 60, 1988, pages 1993-2001)

• TEM microscopy analysis in 1974-75, in raw water from water treatment plants located Waukegan, IL – Burns Harbor, IN:
  – Range: 420,000-4,200,000 f/liter, 2.0-8.0 $\mu$m long, approximately 50% of fibers ranged from 2.0 to 5.0 $\mu$m in length). 80% of total appeared to be chrysotile (McMillan, Lilia M., Roy G. Stout, and Benjamin Willey, Asbestos in Raw and Treated Water: An Electron Microscopy Study, *Environmental Science and Technology*, Volume 11, Number 4, April, 1977 pp 390-394)
Study Design- Sample preparation and analysis

Why the Superfund/Elutriator Method?

- Needed low analytical sensitivity, high specificity
- Sample collection presents data as fibers per gram of PM$_{10}$ (Respirable fraction of particles)
- Analytical method counting rules see more fibers & provide relevant physical characteristics
  - Asbestos mineral type
  - 7402 (PCME) Method: Fiber length > 5 $\mu$m, diameter >0.25 $\mu$m
  - Protocol Structures: Fiber length > 5 $\mu$m and > 10 $\mu$m, diameter < 0.5 $\mu$m
- Measurement serves as input for emission and dispersion models that can predict airborne exposures of PM$_{10}$
Advantages and disadvantages of method

- Very sensitive; for perspective, 10 samples from this study analyzed with PLM (traditional analysis for bulk), all results non-detect
- Total fiber content by mass related to PM$_{10}$ content of sand or soil; PM$_{10}$ content related to silt content, perhaps one third or less of silt
- Assuming 1 MS/gram of PM$_{10}$, silt content of 0.3%, asbestos mass to sand mass ratio is 0.00000012% (assuming average PM$_{10}$ fraction of silt is 35%, sand density of 1.6 g/cm$^3$, average asbestos density of 0.6 g/cm$^3$ and average structure length 10 μm & diameter 0.5 μm)
Silt content

* Silt content of soil usually >10%
* Silt content of sand (passing # 200 sieve < 70-75 um):
  - Grant Park Beach 1.0%
  - IBSP North Unit 0.1%
  - IBSP South Unit 0.2%
  - Highland Park Beach 0.3%
  - Oak Street Beach 0.3%
  - North Point Marina 8.3%
  - Waukegan Harbor 9.2%
Sample collection

• Beach sand: Systematic sampling by length and distance from water line to high water mark
• Lake-bottom sand: Systematic sampling by area and depth
On beaches, sample locations determined through transecting lines, from current water line to the high water mark
  – Divided into 12 equal segments
  – 5 sub samples collected at equally spaced locations
On lake-bottom sand, center of 12 equal area segments, 5 sub samples collected at roughly equivalent spaced depths from top to bottom of core of dredge sand.

Samples by area (from above)

Sub-samples by depth (cross-section)

Water line

Top of sediment (sand) to be dredged

Sub-sample collection lines

Bottom of dredged area
Sediment core sampling: Vibracore
Sample size

- Sub-samples 1-2 kg each
- Samples 5-10 kg each
- Homogenized and reduced for duplicates and splits
- Approximately 70 grams placed in dust generator for each run, agitated & separated in elutriator
- Respirable fraction collected on air filters for microscopy
- Each fiber on filter represents approximately 1 MS/gPM after conversions
Sieving sample
Homogenizing with riffle splitter
Figure 6-3: Dust Generator Modifications

No. 4 rubber stoppers

No. 8 rubber stopper

From Figure A-1 of Berman and Kolk (1997)
Summary statistics

- Total structures counted, Protocol & 7402: 234
- Protocol = 79% of total
- 7402 = 63% of total
- Protocol chrysotile: 79, 77% >10 μm long
- 7402 chrysotile: 39
- Protocol amphiboles: 106, 40% >10 μm long
- 7402 amphibole: 108

Correlation of Total 7402 & Total Protocol Structures

\[ y = 0.9337x \]

\[ R^2 = 0.7359 \]
## Summary of Sampling Results by Location: Sum of NIOSH Method

### 7402 Structures and Protocol Structures

<table>
<thead>
<tr>
<th></th>
<th>Beaches Tested, North to South</th>
<th>Lake-bottom Sand Locations Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grant Park, So. Milw, WI</td>
<td>North Point Marina</td>
</tr>
<tr>
<td></td>
<td>IBSP North Unit</td>
<td>Approach Channel Waukegan Harbor</td>
</tr>
<tr>
<td></td>
<td>IBSP South Unit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highland Park</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oak Street Beach</td>
<td></td>
</tr>
<tr>
<td><strong># of samples collected</strong></td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td><strong># Samples Positive for Asbestos</strong></td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td><strong>Minimum Concentration (MS/g PM$_{10}$)</strong></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Maximum Concentration (MS/g PM$_{10}$)</strong></td>
<td>0.97</td>
<td>5.9</td>
</tr>
<tr>
<td><strong>Average (MS/g PM$_{10}$)</strong></td>
<td>0.16</td>
<td>1.22</td>
</tr>
<tr>
<td><strong>95% UCL of Mean (MS/g PM$_{10}$)</strong></td>
<td>0.64</td>
<td>3.34</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>0.38</td>
<td>1.68</td>
</tr>
<tr>
<td><strong>Median (MS/g PM$_{10}$)</strong></td>
<td>0</td>
<td>0.98</td>
</tr>
<tr>
<td><strong>% Protocol Structures &gt; 10 cm</strong></td>
<td>100</td>
<td>61.5</td>
</tr>
<tr>
<td><strong>% Amphibole Structures</strong></td>
<td>50</td>
<td>67</td>
</tr>
</tbody>
</table>

### Values

- **Lake-bottom Sand Locations Tested**: 12
- **Approach Channel Waukegan Harbor**: 1.0
- **Median (MS/g PM$_{10}$)**: 0.98
- **95% UCL of Mean (MS/g PM$_{10}$)**: 3.34
- **Standard Deviation**: 1.68
- **Average (MS/g PM$_{10}$)**: 1.22
- **Maximum Concentration (MS/g PM$_{10}$)**: 5.9
- **Minimum Concentration (MS/g PM$_{10}$)**: 0
- **% Protocol Structures > 10 cm**: 100
- **% Amphibole Structures**: 50
- **Beaches Tested, North to South**:
  - Grant Park, So. Milw, WI
  - IBSP North Unit
  - IBSP South Unit
  - Highland Park
  - Oak Street Beach

### Locations Tested

- Grant Park, So. Milw, WI
- IBSP North Unit
- IBSP South Unit
- Highland Park
- Oak Street Beach
- North Point Marina
- Approach Channel Waukegan Harbor

### Additional Information

- **Highland Park**
- **Oak Street Beach**
- **North Point Marina**
- **Approach Channel Waukegan Harbor**

- **Beaches Tested, North to South**: Beaches are tested from north to south.
- **Threshold Values**:
  - Average Concentration (MS/g PM$_{10}$): 0.16
  - Maximum Concentration (MS/g PM$_{10}$): 0.97
  - Minimum Concentration (MS/g PM$_{10}$): 0
- **Protocol Structures > 10 cm**:
  - 100% for Highland Park
  - 61.5% for Oak Street Beach
  - 0% for Grant Park, So. Milw, WI
  - 0% for IBSP North Unit
  - 0% for IBSP South Unit
  - 0% for North Point Marina
  - 0% for Approach Channel Waukegan Harbor

- **Amphibole Structures**:
  - 50% for Highland Park
  - 67% for Oak Street Beach
  - 75% for Grant Park, So. Milw, WI
  - 0% for IBSP North Unit
  - 0% for IBSP South Unit
  - 0% for North Point Marina
  - 0% for Approach Channel Waukegan Harbor
  - 29% for Highland Park
Comparison to another bulk method

Comparison of Superfund and Sonication/Water Methods

\[ y = -1E-05x + 221.23 \]

\[ R^2 = 0.0592 \]
Statistically Significant Differences (total concentrations) using Mann-Whitney Test

- Oak Street Beach results excluded for study comparisons, not known if results typical for urban areas or influenced by unknown factors
- IBSP South Unit not significantly different from Highland Park and Grant Park Beaches
- IBSP North Unit, Waukegan Harbor Approach Channel, & North Point Marina significantly different from Highland Park and Grant Park Beaches
Exposure & risk assessments

- Inhalation exposure is most relevant, complete pathway
- Assessing risk from exposure to asbestos in soil (sand, in this case), is a difficult issue nationwide
- PM$_{10}$ emissions models
- Toxicity: Role of structure length, diameter, type long debated in scientific community, still emerging science
Discussion

- Largest current study of its kind
- Study data is credible, interpretable
- Presence of ACM not closely related to asbestos concentrations in sand by this method
- Samples collected at historically low lake level
- Role of lake water dynamics: Silt, small particulate move off beach into lake
Recommendations for IBSP

• No reason to exclude beach nourishment from lake-bottom sand sources if deposited offshore
• Increased beach surveillance for ACM
• Improved visitor education about ACM
• Inspection and surveillance of areas with remaining housing infrastructure
• Exploration of other options for beach nourishment or erosion reduction