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Aggressive Air Sampling and Bio-Event Restoration:

Current Status and Future Potential

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Outline

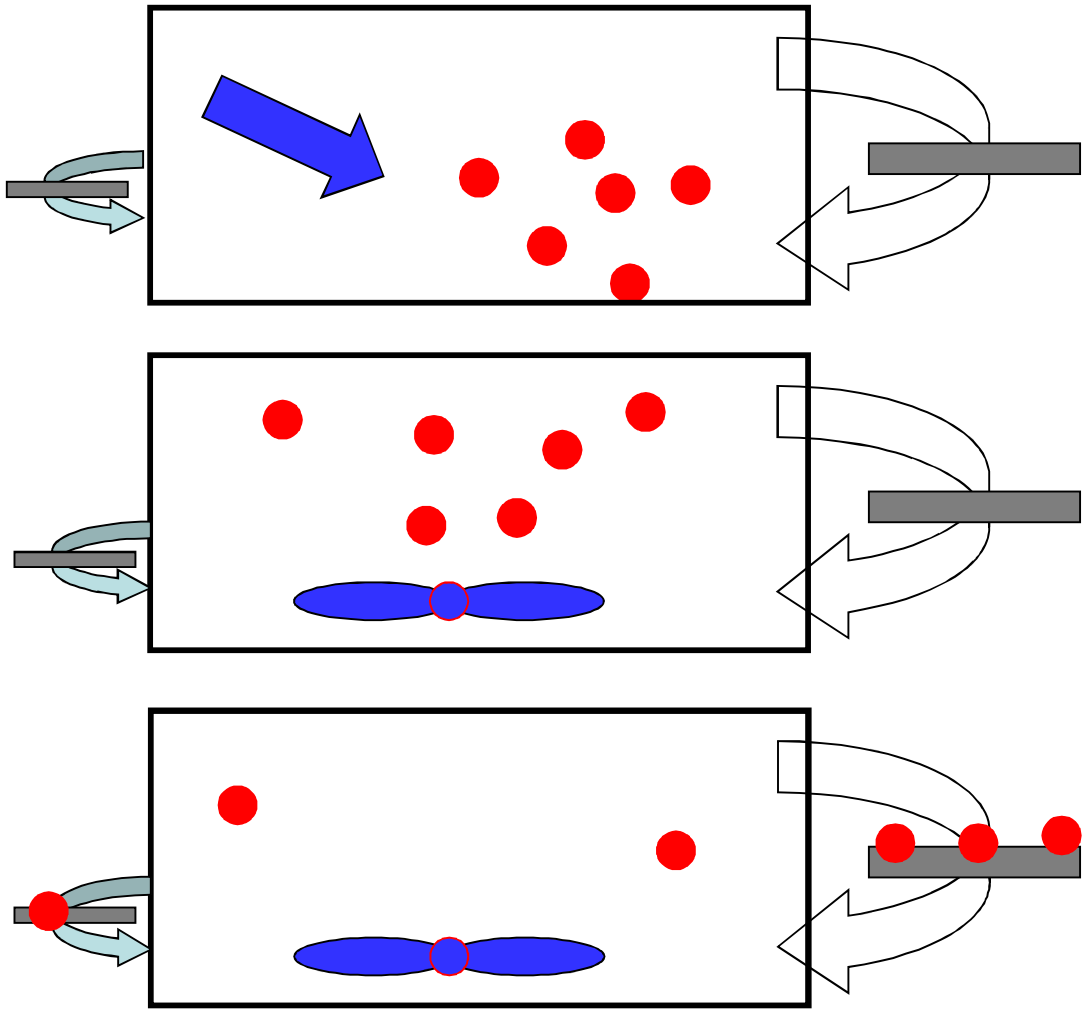
- What is AAS and how could it be used?
- Outstanding Issues
- Current Guidance and Application
- Initial Sensitivity Analysis
- Laboratory Studies
- Analysis and Statistics
- Proposed Tasks

Aggressive Air Sampling

- Apply forced air to surfaces to resuspend particles
- Keep them suspended and keep room under negative pressure
- Continuously sample the air

AAS has been employed in all anthrax restoration projects to date

Aggressive Air Sampling



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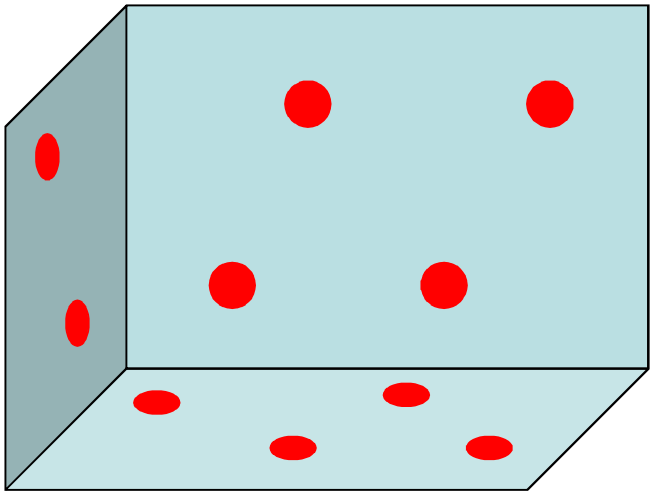
Characterization and Clearance

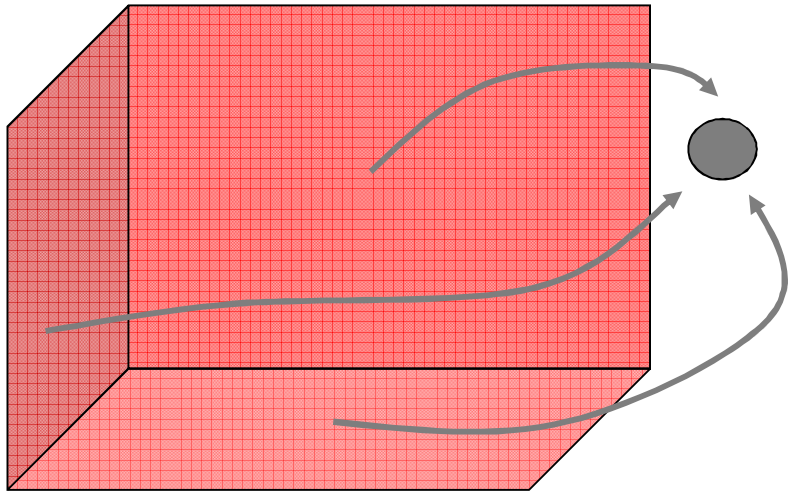
- The first question in characterization:
  - Can we rule out facility areas from requiring any additional sampling?
  - Need for rapid screening of areas (clean/contaminated)
- Large research focus now on reducing the number of clearance samples necessary
  - Bayesian Approaches
  - Taking account of spatial correlation
  - Compositing approaches

- Acquiring, recording, analyzing and documenting samples is time consuming
  - *Sampler must be applied to all the surfaces*

Comparing Approaches

- Currently we acquire multiple samples on room surfaces
- Ideally, have one sample per room volume that concentrates any contamination onto a single filter
  - *Bring the surfaces to the sampler (Concentrate)*

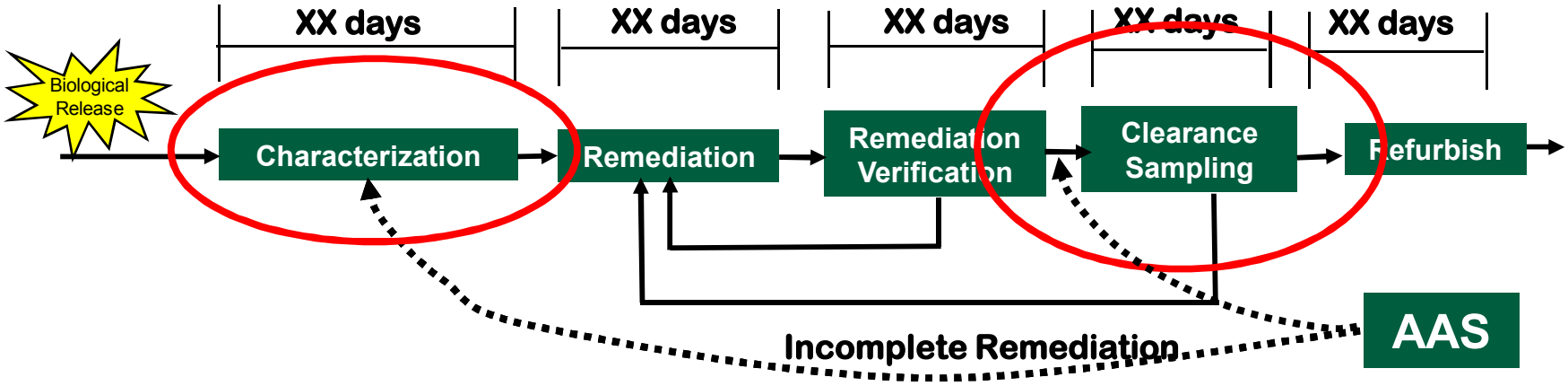




Operationally, AAS could be used as a rapid screening tool!

How Would AAS be Used (Facilities)?

In facility restoration projects, characterization and clearance sampling is time consuming and expensive. If Remediation has failed, both remediation and clearance sampling must be redone



AAS should be considerably faster than current characterization and clearance sampling and could be employed as part of the Remediation Verification process

Using the same HVAC setup and flow boundaries as decontamination. If AAS is not successful, redo decontamination immediately

If AAS is successful use that information to reduce samples

How Would AAS be Used (Facilities)?

Example Bayesian analysis of clearance:

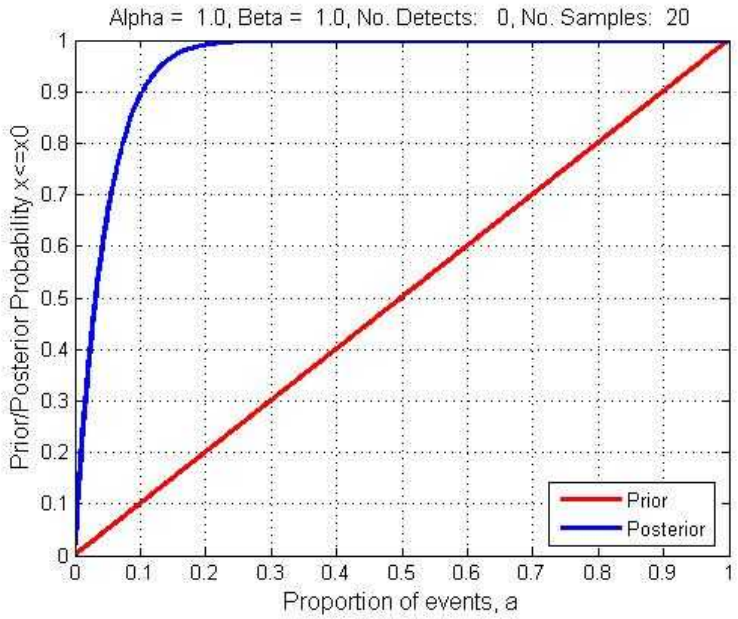
2 levels of prior knowledge

- No information on remaining contamination (Uninformed Prior)
- Small chance of any bio-agent remaining (Low Prior)
  - Decon process met all criteria and AAS results were negative

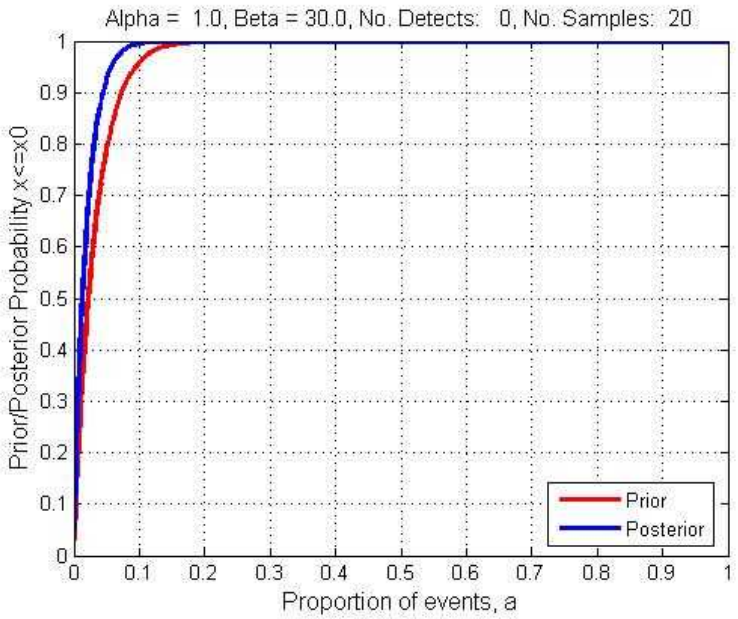
In both cases, 20 samples are obtained, all are negative, what is the chance that some contamination remains?

How Would AAS be Used (Facilities)?

Uninformed Prior



Low Prior



Direct response to GAO report:

Validated methods to increase confidence in negative responses

How Could AAS be Used (Wide Area)?

- Characterization:
  - Big city, many buildings, many offices
  - Rapid screening of office clusters, floors, buildings (?)
  - Non-infrastructure equipment

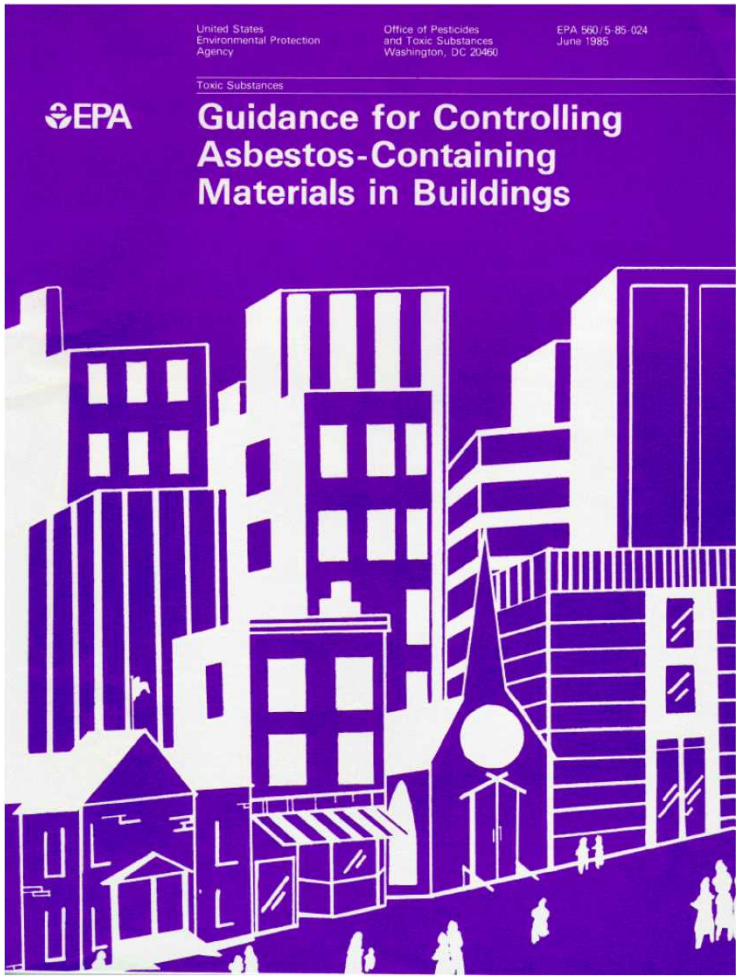
- Clearance:
  - Rapid assessment of decon on same structures
  - Not limited to buildings: Outdoor equipment and materials
    - Drive-in clearance sampling (tent)
  - Aircraft as the “room”

Outstanding Issues

- Gaps in the science:
  - How easily can spores be resuspended?
  - What factors enhance or impede resuspension?
  - How can AAS be validated/verified?
- Gaps in the practice:
  - How long do we sample?
  - What sampling rate is “best”?
  - How to balance the sampling rate with the negative air pressure exchange?
  - Is there a right or wrong way to use the leaf blower?
  - If one sampler is good, are more samplers better?

Current Guidance

- There is no guidance for application of AAS in Bio restoration
- All applications to date have been based on guidance published for asbestos (EPA 1985)
  - Can lead to fairly ad hoc applications (not defensible)



U.S. EPA, 1985, "Guidance for Controlling Asbestos-Containing Materials in Buildings, (EPA 560/5-85-024)

Summary of Asbestos Guidance

1) Before starting the sampling pumps, direct the exhaust from forced air equipment (such as a 1 hp leaf blower) against all walls, ceilings, floors, ledges and other surfaces in the room.

   At least 5 minutes per 1000 sq. ft. of floor.

2) Place a 20-inch fan in the center of the room. Place the fan on slow speed and point it toward the ceiling

   Use one fan per 10,000 cubic feet of room space.

3) Ventilation requirements to exchange the air in the room four times every hour

4) Start the sampling pumps and sample for the required time.

5) Turn off the pump and then the fan(s) when sampling is complete.

Asbestos-Based Guidance

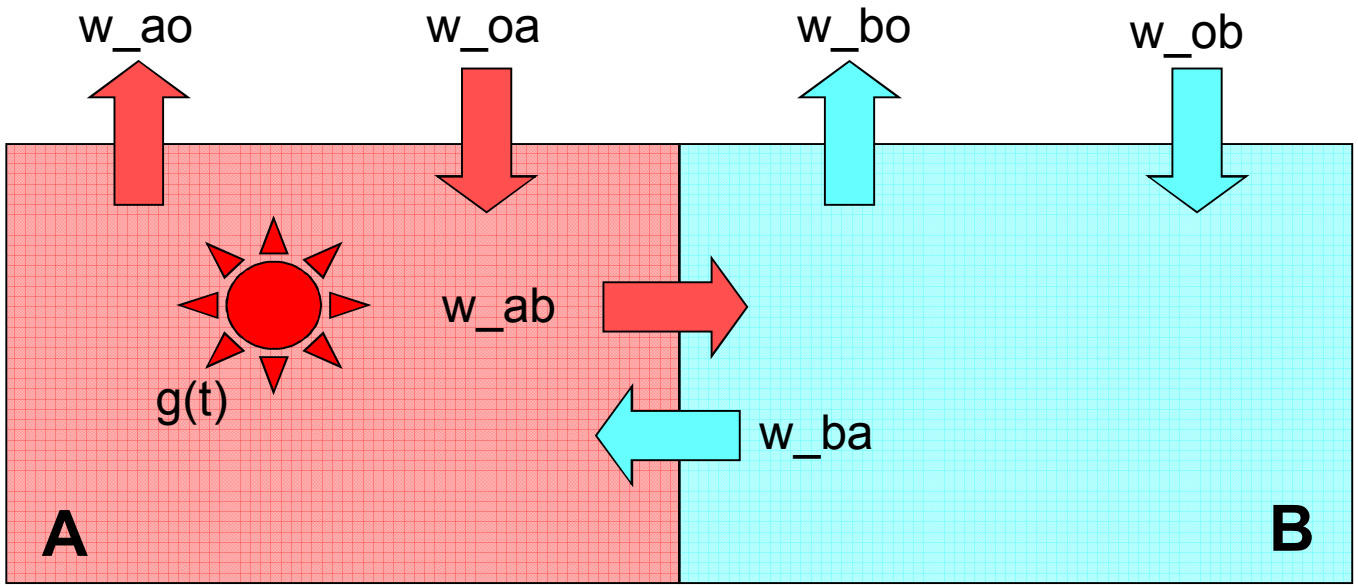
- The EPA guidance provides recommended air sampling volumes
  - These are based on detection limits for prescribed asbestos analyses
  - Not necessarily applicable for AAS of biological agents
- Asbestos fibers vs. spores:
  - Ease of mobilization
  - Settling velocity (time of suspension)
  - Appropriate filter sizes and efficiencies
  - Analysis technique (optical vs. culture)

Sensitivity Analysis

- Simple conceptualization of the AAS process using a “two-compartment” model
- Start to get a feel for how different parameters can influence the results
  - Overall goal is to maximize the chance of finding any contamination if it is present
- Analytical solution evaluated with a spreadsheet tool

Two-Compartment Model

- Developed for modeling concentration of smoke in a two room building



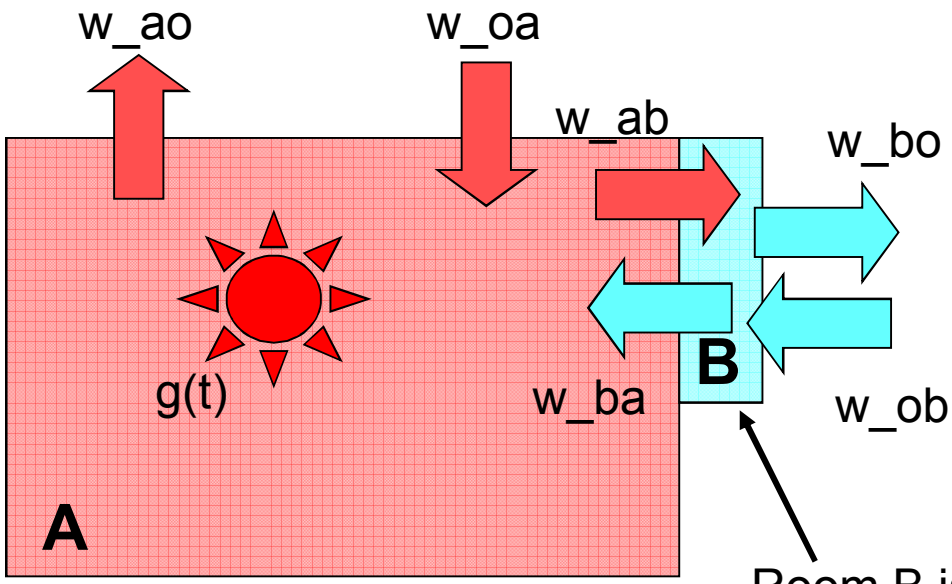
Ott,W.R., N.E. Klepeis and P. Switzer, 2003, Analytical Solutions to Compartmental Indoor Air Quality Models with Application to Environmental Tobacco Smoke Concentrations Measured in a House, *Journal of the Air and Waste Management Assoc.*, 53, pp. 918-936.

Model Assumptions

- Application of the solutions developed by Ott et al., 2003 to the problem of AAS for particulates require some assumptions:
  - The particulates behave as perfect tracer (settling velocity is zero and they do not clump together)
  - The source is an instantaneous pulse that completely mixes the source mass throughout the room volume at time = 0 (other options available)
  - The outdoor concentration remains negligible throughout the modeled time period (infinite sink)

Model Adaptation

Losses to the negative pressure exchange are conceptualized as losses to the “outdoors”



Losses to the filter in the sampler are conceptualized as losses to the “outdoors”

Room B is the sample chamber (small volume)

w_ao and w_ab are flow rates to the negative air exchange and the sampler, respectively

Sampler efficiency = w_bo / (w_bo + w_ba)

Modeling Questions

- How long is it necessary to run the air samplers?
- What is the optimal sampling rate to air exchange rate ratio?
  - Goal is to detect any remaining contaminant
- How does sampler filter efficiency affect the results?
- Are two or more samplers better than one?

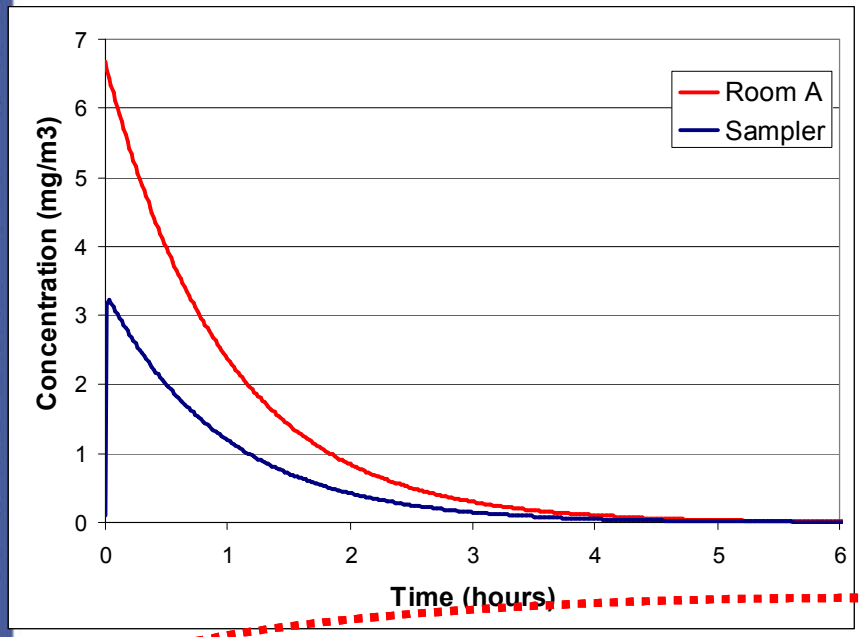
Model Results

Room and sampler volumes: 150m^3 and 0.1m^3

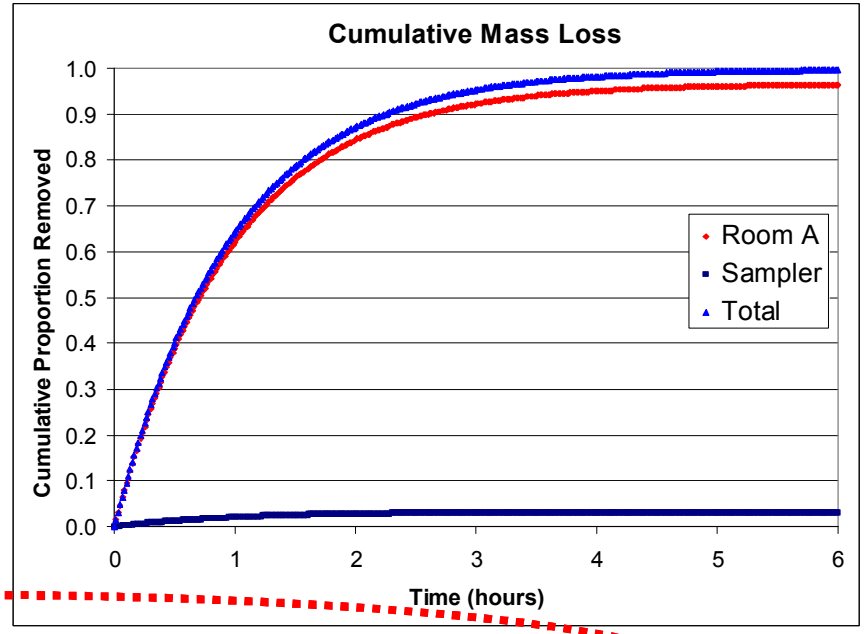
Filter efficiency: 0.50

Air exchange and sampling rates: 150m^3/hr and 10m^3/hr (88 cfm and 5.9 cfm) (1 room exchange per hour)

Concentration



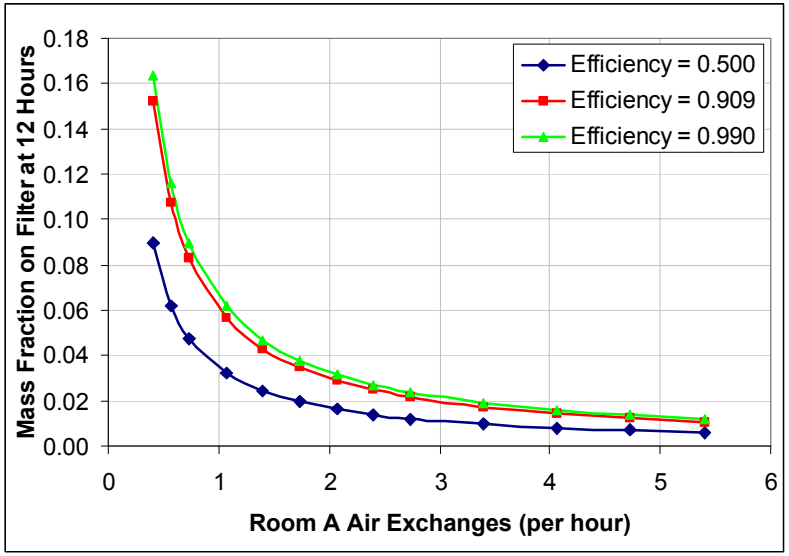
Cumulative Mass Loss



3.2% of initial mass makes it to the filter after 12 hours

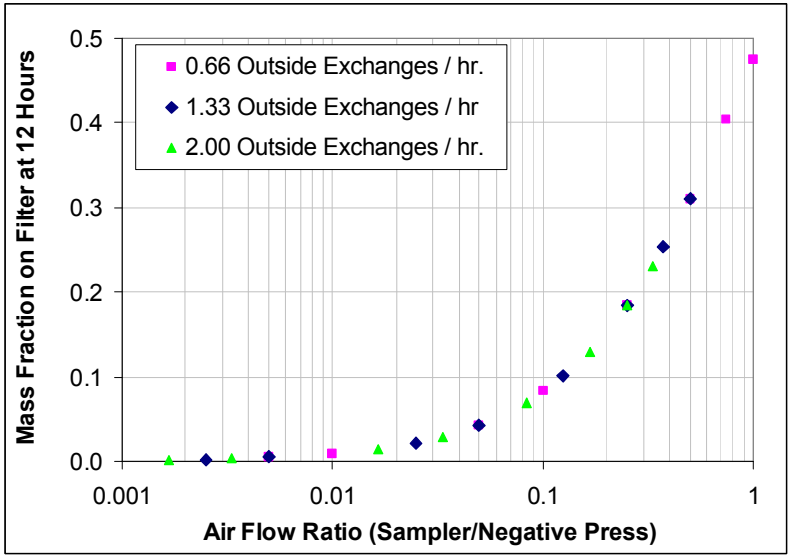
Model Results (Cont)

Effects of filter efficiency and room exchanges per hour on fraction of mass recovered on filter at 12 hours



Limit air exchanges to less than one per hr. and get sampler efficiency to 90 percent or better

Effects of sampling / air exchange rate and room exchanges per hr. on fraction of mass recovered on filter (12 hrs)



Keep sampler/air exchange rate ratio near 1.0 and limit the number of air exchanges per hr

Does increasing number of samplers help with mass recovery?

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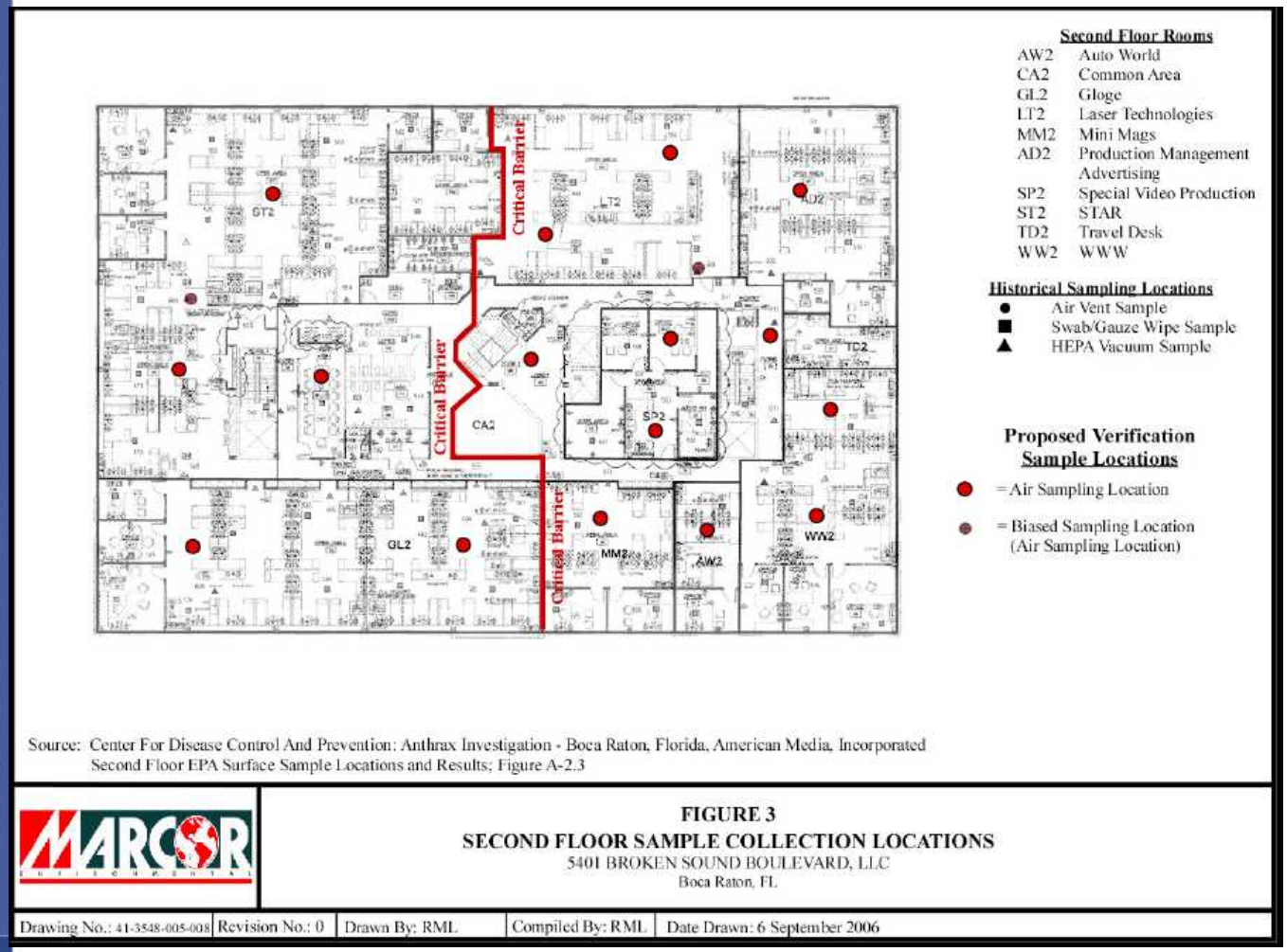
Example (5401 Broken Sound Blvd.)

Most recent application of AAS for clearance sampling



Look at a rough calculation for the west half of the second floor using proposed design

Air sampling using 8 DFU's pull 0.3 m^3/min (10.6 ft^3/min) each

Room Volume = 4417m^3 (156,000 $ft^{3)}$

Negative flow rate provided by AHU 1: approx 156 m^3/min (5500 ft^3/min)

Sampling time = 92 hours

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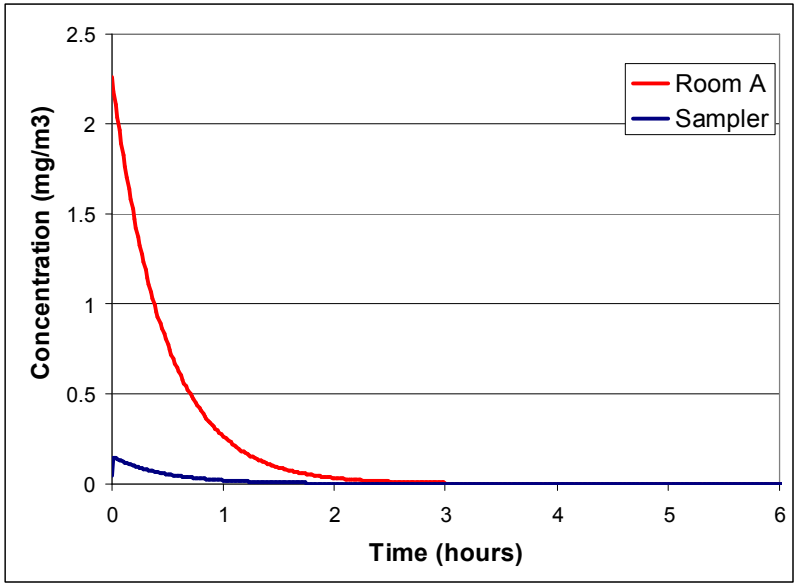
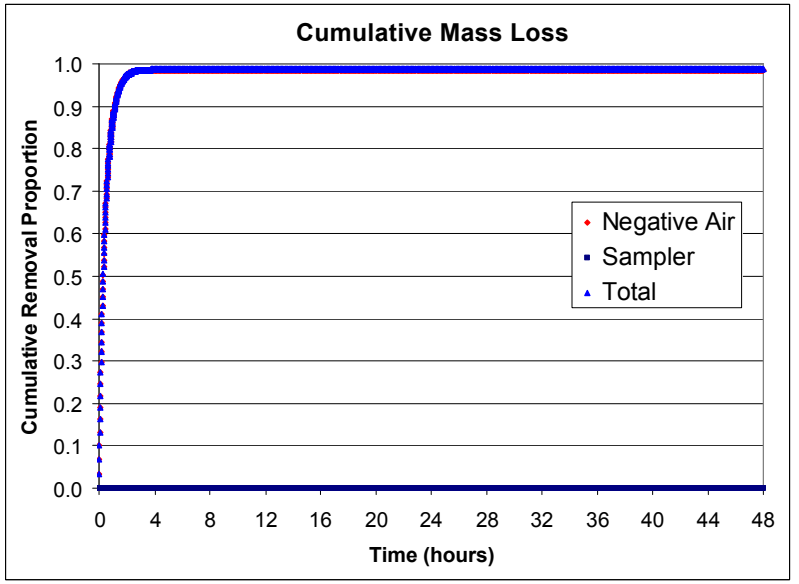
Example Calculations

- Volumes:
  - Room = 4417m^3, 8 samplers = 1.0m^3
- Flow rates:
  - Negative air = 9360m^3/hr (2+ exchanges per hour)
  - 8 Samplers = 144m^3/hr
- Sampler Efficiency
  - Set to 93.3% (assumed value)
- Initial spore count
  - 10,000 (hypothetical value)
- Sampling time of 92 hours

Calculation Results





Results stabilize by 3.5 hours

1.3% of any possible spores are captured on sampler, 98.7% leave via negative air exchange

These calculations use an unvalidated model, include coarse assumptions and serve as an explanatory example only.

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Particle Retention

Relative humidity may control the ability of blowers to resuspend particles after they have attached to a surface

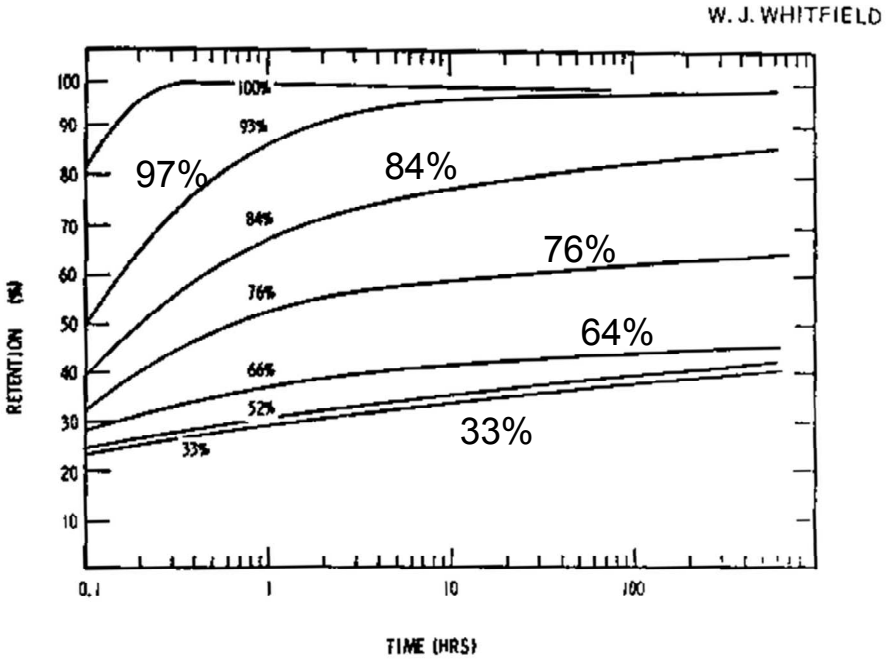


Figure 8. Effects of relative humidity on surface particle retention.

Particles are deposited onto metal coupons, photographed and then subjected to a 10 second long, 20psi air blast at ½ inch and photographed again

$$Retention \quad \% = \frac{NP_{after}}{NP_{before}} x100$$

Thanks to B. Skolnik for providing this reference

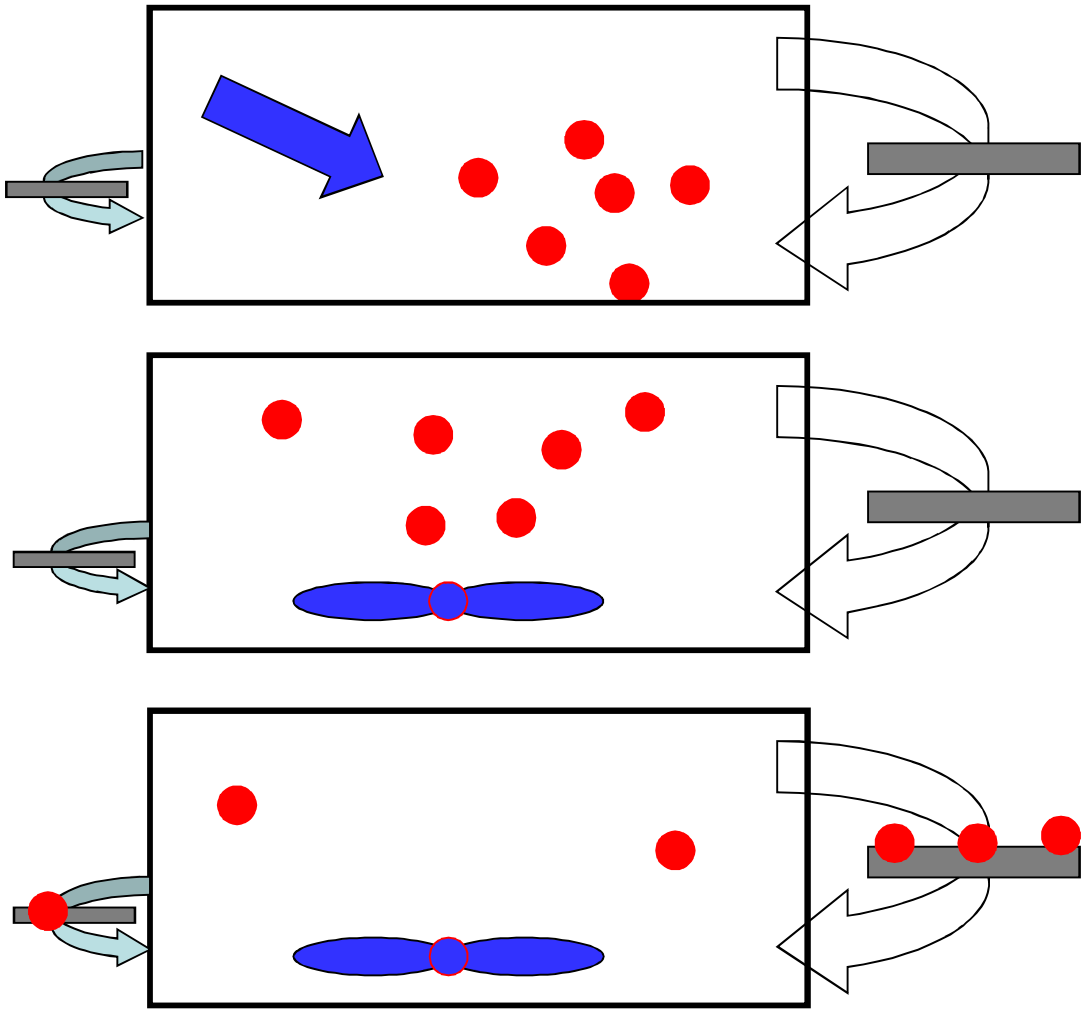
Whitfield WJ.,1979, A study of the effects of relative humidity on small particle adhesion to surfaces. In: *Surface Contamination: Genesis, Detection and Control, Vol. 1*, Mittal KL, ed. Plenum Press, New York, pp. 73-81.

Experimental Work

- What is needed to reaerosolize spores?
  - Leaf blowers (directed air blast, angle, timing)
  - Relative humidity (note ClO_2 fumigant is generally used at 75% RH)
  - Various surface materials (painted wallboard, carpet, tile, concrete)

- Has blindly adopting the asbestos approach steered us down the wrong path? (next slide)

Where are the spores?



If air exchange rates are much larger than sampling rates, bias is toward spores ending up on HVAC filter

Can Native Air Sampling techniques be used to analyze HVAC filters for spores?

Analysis and Statistics Work

- Optimal setting of air exchange and sampling rates
- What qualifies as a room?
  - Does it have to be an enclosed space under nearly equilibrium negative pressure?
  - Can it be an open floor with multiple negative pressure units?
- Applying confidence to results
  - What is confidence in mass recovery? (pre-screening)
  - How to change prior distribution for clearance sampling?

What Needs to be Done?

- Build the S&T basis that supports appropriate guidance for application of AAS in facility restoration
  - Model calculations to identify proper exchange and sampling rates
  - Experimental investigation to identify resuspension mechanisms and validate models
  - Provide statistical basis for determining whether or not the facility is contaminated and reduction of clearance samples
  - Systems analysis to identify best use of AAS in both indoor and outdoor settings

Downstream Products

- Fit AAS into characterization and clearance sampling protocols for prescribed confidence
- Guidance
  - Guidance document and software for facility restoration personnel
  - Recommended tools for AAS (blowers, samplers, etc.)

Phased Budget

- *Year 1,Task 1:* Evaluate current reaerosolization methods on different surfaces and humidities using *BG* ($600k)
- *Year 1,Task 2:* Understand and optimize the system that collects the spores and contains them ($350k)

- *Year2 Task 1:* Demonstrate prototype optimized system on an existing building or other (with *BT*)
- *Year 2 Task 2:* Develop and publish guidance document and protocols
- *Year 2 (Follow-on Task 1):* If less than optimal results, investigate improved methods for dislodging
- *Year2 (Follow-on Task 1):* If sampling efficiencies cannot be increased, then look at other options (e.g., native air sampling)

Summary

- AAS is currently in use for clearance confirmation
  - Indications are it is not being used effectively and there is no basis for understanding the results
- AAS has huge potential in a Pre-Screening role for use in facility and wide area restorations
  - Decrease sampling effort (characterization & confirmation)
- Outstanding S&T issues that must be addressed before AAS can be applied in restoration scenarios
- Direct path from S&T work to downstream products for restoration teams