



**Surface Sampling Areas
Required
to Inform Risk-based Responses
to *B. anthracis* Contamination**



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Outline

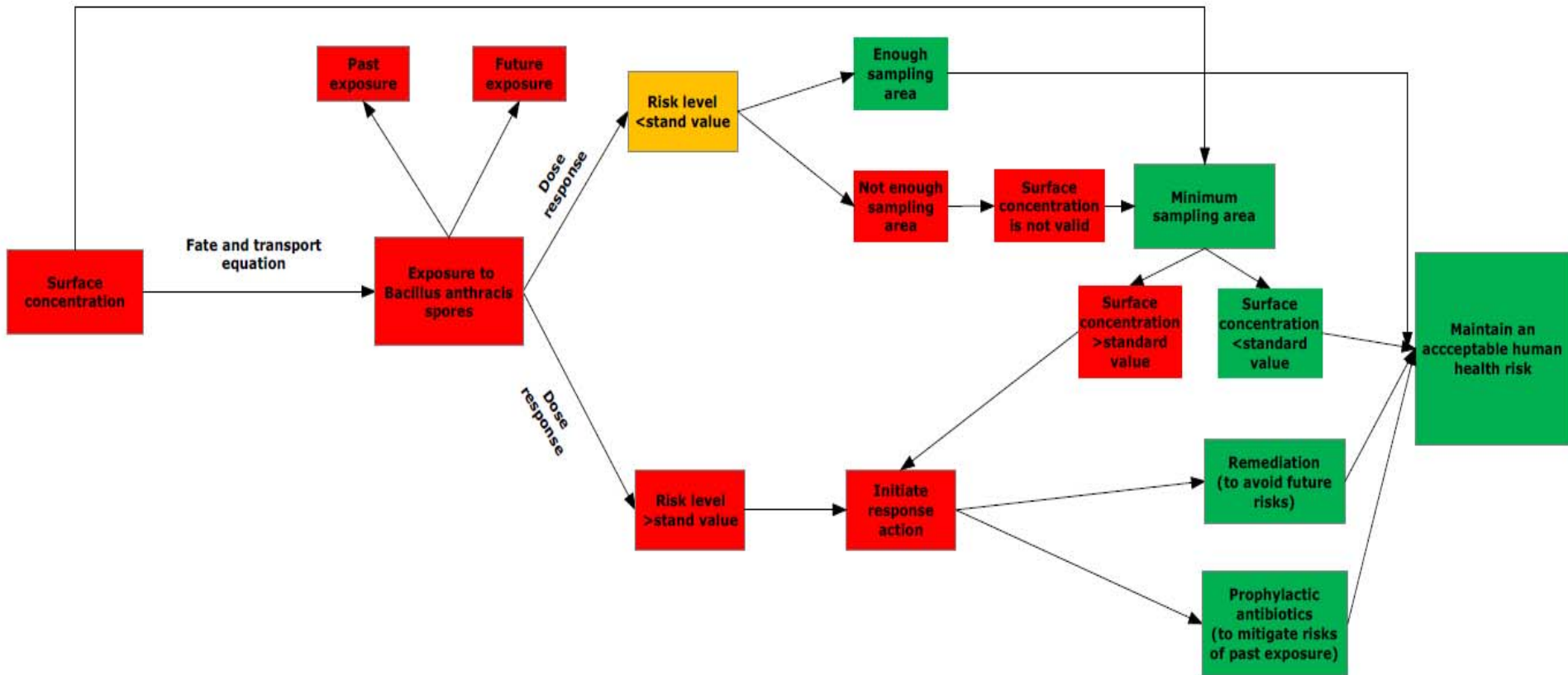
- Introduction
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Introduction

- Human health retrospective (prospective) risk from biological agents is associated with previous (future) aerosol exposures
- Aerosol exposures could be estimated by agents' concentrations found on surfaces
- Sometimes, non-detect result may not establish risk below value with confidence level
- A minimum sampling areas are required to demonstrate compliance with surface concentration standards are developed

Flow chart

Analytical equation + classical statistical inference



Risk Scenario

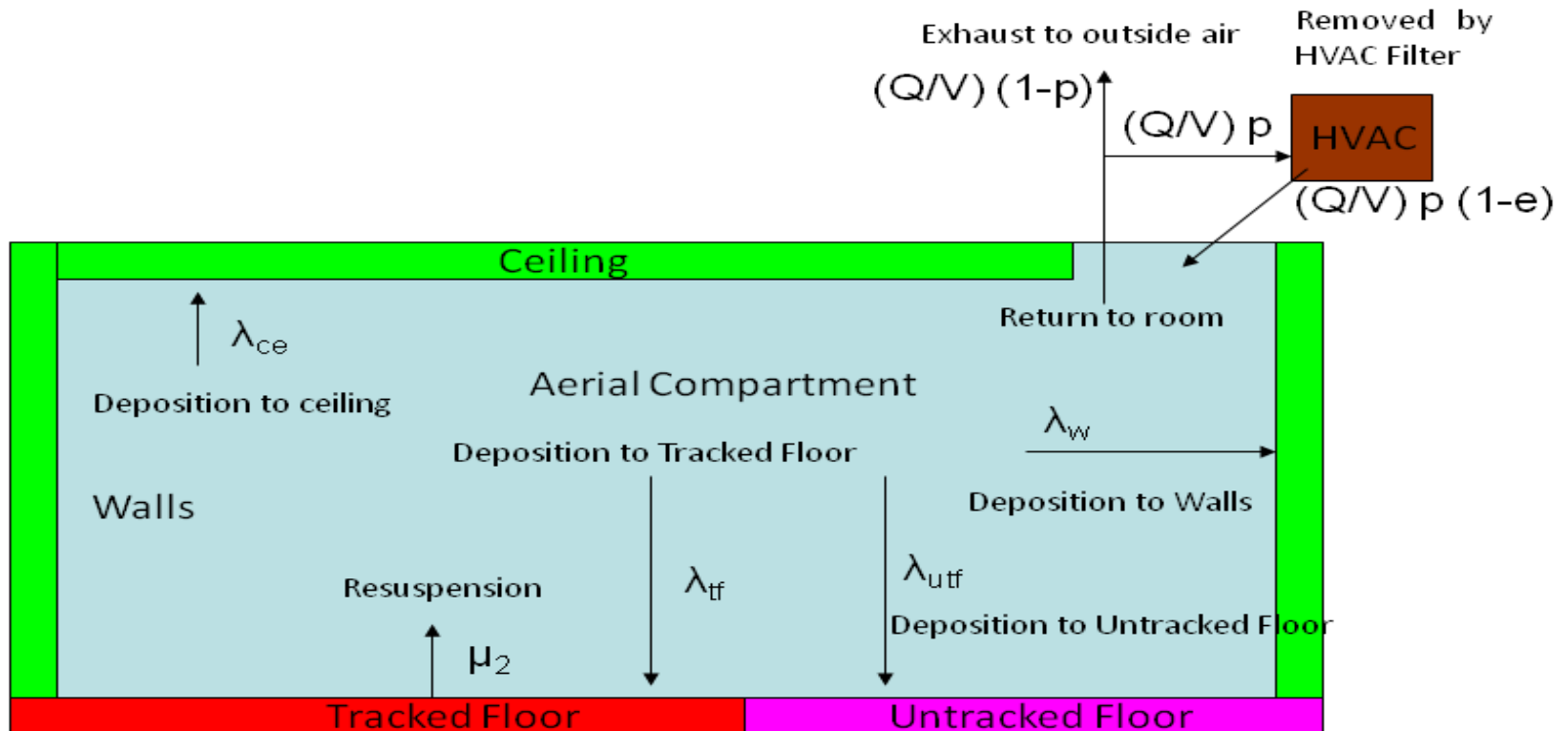
- *Bacillus anthracis* spores were released in the air
- Assuming an average breathing rate
- Exposure time is 8 hours
- Estimating the likely number of anthrax spores inhaled
- Using dose-response models to estimate the probability of mortality given certain exposure dose.

Method

- Using fate and transport model to compute surface concentration

We divide the office into 7 internal compartments:

- 1) air, 2) tracked floor, 3) untracked floor, 4) walls, 5) ceiling, 6) HVAC, and 7) the nasal passages



Caveats

- Uniform concentration (complete mixing) of spores
 - Appropriate for small size fraction downwind of and/or after initial release
- Use of high dose animal model for low dose human exposure

Dose-response

- Using dose-response model to estimate risk level
- Exponential dose-response model

$$\text{risk} = 1 - \exp(-r \text{ dose})$$

- Beta-Poisson dose-response model

$$\text{risk} \approx 1 - \left(1 + \frac{\text{dose}}{\beta}\right)^{-\alpha}$$

Minimum sampling area (MSA)

- Employing MSA to check the correctness of the result
- Rejecting the hypothesis that the concentration exceeds the standard with a sufficient level of confidence $1 - \alpha$

$$H_0: \text{Concentration} > C_{\text{stan}}$$

- Assuming that the spores are distributed on the surface according to a Poisson distribution

$$\sum_{X=0}^{DL-1} \frac{e^{-(AC)} (AC)^X}{X!} < \alpha$$

- X is the number of organisms, DL is the detecting limit of spores, A is the sampling area, and C is the surface concentration

Using Bayesian updating method to optimize surface concentration

- Bayesian statistical updating method allows the option of bringing prior information to bear on a problem

$$f(\lambda_j | C) = \frac{f(C | \lambda_j) f(\lambda_j)}{\sum_{i=1} f(C_i | \lambda_i) f(\lambda_i)}$$

$$f(C | \lambda_i) = \frac{e^{-\lambda_i} \lambda_i^{(C)}}{(C)!}$$

- λ is the long run surface concentration, C is the number of counts measured on the surface
- The initial concentration prior probability $f(\lambda_j)$ comes from mechanistic modeling of release

Example

- Model inputs

Symbol	Meaning	units	Value	Source	
V	Room dimensions	m ³	5.6×5.6×2.5	Assumed a typical office (EPA 1997; RG Sextro 2002)	
A _{tr}	Area-tracked floor	m ²	5.6×5.6×0.75		
A _{untr}	Area-untracked floor	m ²	5.6×5.6×0.25		
A _{ce}	Area- ceiling	m ²	5.6×5.6		
A _w	Area- wall	m ²	5.6×2.5×4		
A _f	Filter area	m ²	3.82×10 ² (2.81×10 ² -5.62×10 ²)	Q/A = 137m/min (91-183 m/min)	
A _n	Area of nasal passages	m ²	0.8	(Landahl 1950)	
ACH	Air changes per hour		4	(ASHRAE 2005)	
Q	Discharge	m ³ /min	5.23	Q = V×ACH/60 (in minutes)	
f	Recirculation fraction		0.8	(RG Sextro 2002)	
P	Proportion tracked		0.75	(ASHRAE 2005)	
μ ₂	Resuspension rate	hr ⁻¹	D=1μm	1.2×10 ⁻⁴	(Thatcher and Layton 1995; RG Sextro 2002)
			D=3μm	1.9×10 ⁻³	
			D=5μm	0.8×10 ⁻³	
			D=10μm	0.4×10 ⁻²	
e	Filter efficiency		D=1μm	0.098	(RG Sextro 2002)
			D=3μm	0.49	
			D=5μm	0.74	
			D=10μm	0.88	

Example

- Model inputs (continued)

Symbol	Meaning	Units	Diameter	Lower bound	Source	Upper bound	Source	Input value
V_{uf}	Deposition velocity on untracked and tracked floor	m/s	1 μ m	3.5×10^{-5}	(Lai and Nazaroff 2000)	8.0×10^{-4}	(NRC 2005) (Riley, McKone et al. 2002)	6.9×10^{-5}
			3 μ m	2.0×10^{-4}	(NRC 2005)	6.0×10^{-3}		4.2×10^{-4}
			5 μ m	3.0×10^{-4}		1.4×10^{-2}		1.4×10^{-3}
			10 μ m	7.0×10^{-4}		2.7×10^{-2}		5.6×10^{-3}
V_{uw}	Deposition velocity on walls	m/s	1 μ m	3.5×10^{-9}	(Lai and Nazaroff 2000)	9.0×10^{-5}	(Schneider, Kildeso et al. 1999)	3.9×10^{-5}
			3 μ m	1.5×10^{-8}		2.1×10^{-4}		1.6×10^{-4}
			5 μ m	1.0×10^{-8}		4.0×10^{-4}		3.1×10^{-4}
			10 μ m	7.0×10^{-9}		6.0×10^{-4}		3.5×10^{-4}
V_{ce}	Deposition velocity on ceiling	m/s	1 μ m				(NRC 2005)	6.2×10^{-7}
e_n	Nasal passages particle remove efficiency		1 μ m	0.02	(Landahl 1950)		(Roger O. McClellan and Henderson 1989)	
			3 μ m	0.22		0.25		0.14
						0.68		0.45
			5 μ m	0.42		0.81		0.62
			10 μ m	0.62		0.91		0.77
r	Probability of a single Bacillus anthracis spore initiating infection		1-5 μ m	9.1×10^{-7} (95% confidence interval)	(Jade Mitchell-Blackwood, Patrick L. Gurian et al. 2008)	7.0×10^{-5} (95% confidence interval)	(Jade Mitchell-Blackwood, Patrick L. Gurian et al. 2008)	7.2×10^{-4}
			10 μ m	1.0×10^{-7} (95% confidence interval)	Extrapolated from (Jade Mitchell-Blackwood, Patrick L. Gurian et al. 2008)	8.1×10^{-4} (95% confidence interval)	Extrapolated from (Jade Mitchell-Blackwood, Patrick L. Gurian et al. 2008)	8.2×10^{-7}
risk	Acceptable risk level			1.0×10^{-5}	(Mitchell-Blackwood and Gurian 2008)	1.0×10^{-3}	(Travis, Richter et al. 1987)	1.0×10^{-4}
Inh	Breathing rate	m ³ /hr		0.8	(Kowalski 2003)	2.0	(Kowalski 2003)	1.02

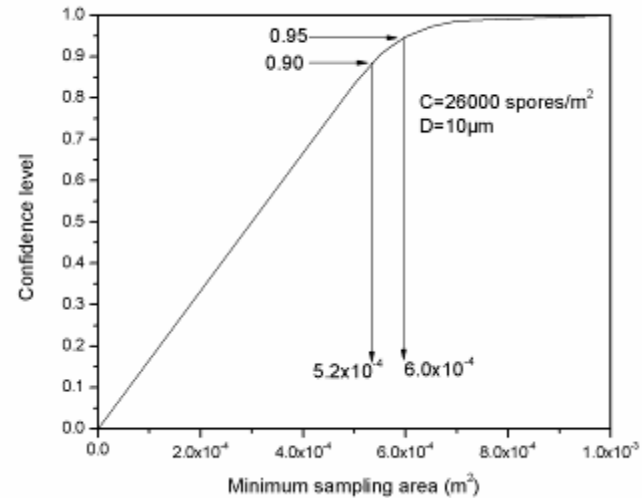
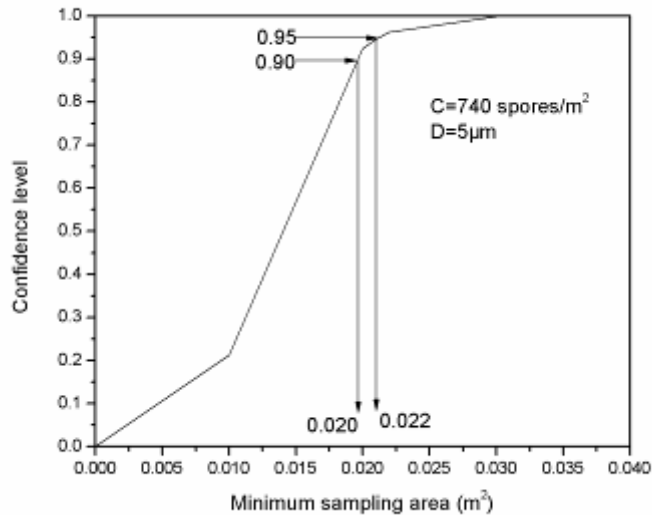
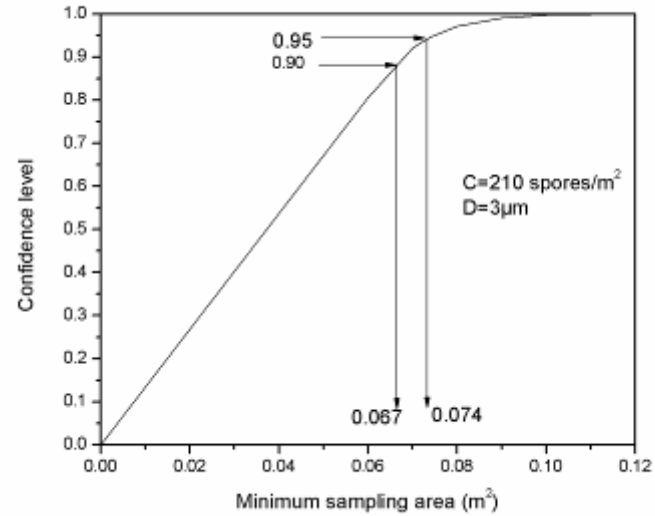
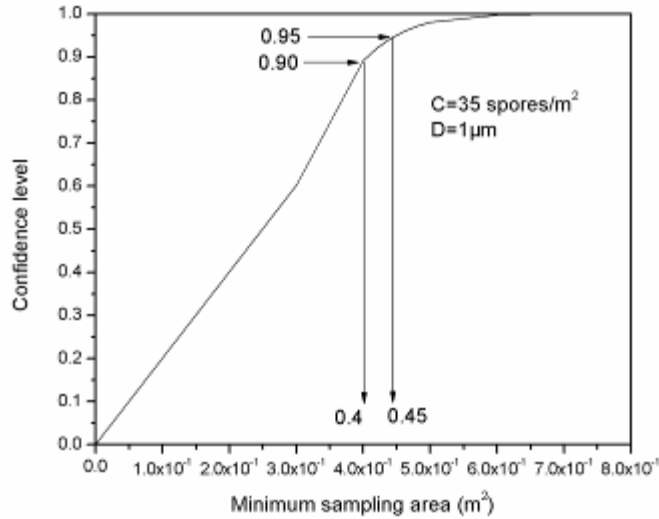
Result

Minimum sampling area and surface concentration after a 8 hours releasing
Risk level=0.001

Diameter (μm)	Amount of Initial Release (Range) (spores/ m^2)	Untracked or Tracked floor (Range) (spores/ m^2)	MSA (Range) (m^2)	Walls (Range) (spores/ m^2)	MSA (Range) (m^2)	Filter (Range) (spores/ m^2)	MSA (Range) (m^2)	Nasal Passages (spores/ m^2)	MSA (Range) (m^2)
1	1.5×10^4 ($2.4 \times 10^3 - 5.7 \times 10^5$)	35 ($8.8 \times 10^{-1} - 4.0 \times 10^3$)	0.50 ($4.3 \times 10^{-3} - 19$)	20 ($8.8 \times 10^{-4} - 4.5 \times 10^2$)	0.84 ($3.8 \times 10^{-2} - 1.9 \times 10^0$)	8.8×10^4 ($38 - 1.5 \times 10^6$)	1.9×10^{-4} ($1.1 \times 10^{-5} - 4.4 \times 10^{-3}$)	24 ($0.36 - 3.4 \times 10^2$)	0.68 ($4.9 \times 10^{-2} - 47$)
3	3.8×10^4 ($2.5 \times 10^3 - 1.3 \times 10^6$)	2.1×10^2 ($5.1 - 3.0 \times 10^0$)	8.0×10^{-2} ($5.7 \times 10^{-4} - 3.4$)	79 ($3.8 \times 10^{-4} - 1.0 \times 10^3$)	0.21 ($1.6 \times 10^{-2} - 4.5 \times 10^0$)	4.4×10^5 ($1.9 \times 10^2 - 7.5 \times 10^6$)	3.7×10^{-5} ($2.2 \times 10^{-4} - 8.8 \times 10^{-2}$)	78 ($3.9 - 9.3 \times 10^2$)	0.20 ($1.8 \times 10^{-2} - 4.3$)
5	7.0×10^4 ($2.7 \times 10^3 - 3.3 \times 10^6$)	7.4×10^2 ($7.6 - 6.9 \times 10^0$)	2.3×10^{-2} ($2.4 \times 10^{-4} - 2.2$)	1.5×10^2 ($2.5 \times 10^{-4} - 2.0 \times 10^3$)	0.10 ($8.5 \times 10^{-3} - 6.7 \times 10^0$)	6.6×10^5 ($2.9 \times 10^2 - 1.1 \times 10^7$)	2.3×10^{-5} ($1.5 \times 10^{-6} - 5.8 \times 10^{-2}$)	108 ($7.5 - 1.1 \times 10^3$)	0.14 ($1.5 \times 10^{-2} - 2.3$)
10	1.3×10^6 ($2.6 \times 10^4 - 6.4 \times 10^7$)	2.6×10^4 ($1.5 \times 10^2 - 1.2 \times 10^6$)	6.5×10^{-4} ($1.4 \times 10^{-5} - 0.1$)	1.5×10^3 ($1.5 \times 10^{-3} - 2.7 \times 10^6$)	1.0×10^{-2} ($1.4 \times 10^{-5} - 1.1 \times 10^0$)	6.9×10^6 ($3.0 \times 10^3 - 1.2 \times 10^9$)	2.2×10^{-4} ($1.4 \times 10^{-7} - 5.7 \times 10^{-3}$)	1.2×10^3 ($96 - 1.1 \times 10^4$)	1.3×10^{-2} ($1.5 \times 10^{-3} - 0.18$)

MSA is computed based on the 95% confidence interval, and $A C_{\text{stan}} \geq 16.96$

Minimum sampling area Vs Confidence level (Untracked floor)



Conclusion

- The proposed framework provides easily usable analytical equations to rapidly estimate risks of *B. anthracis* based on observed surface concentrations.
- The minimum sampling area has a negative relation to surface concentration, particle diameter and elapsed time before sampling.
- The minimum sampling area has a non-linear positive relationship with the confidence level

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