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

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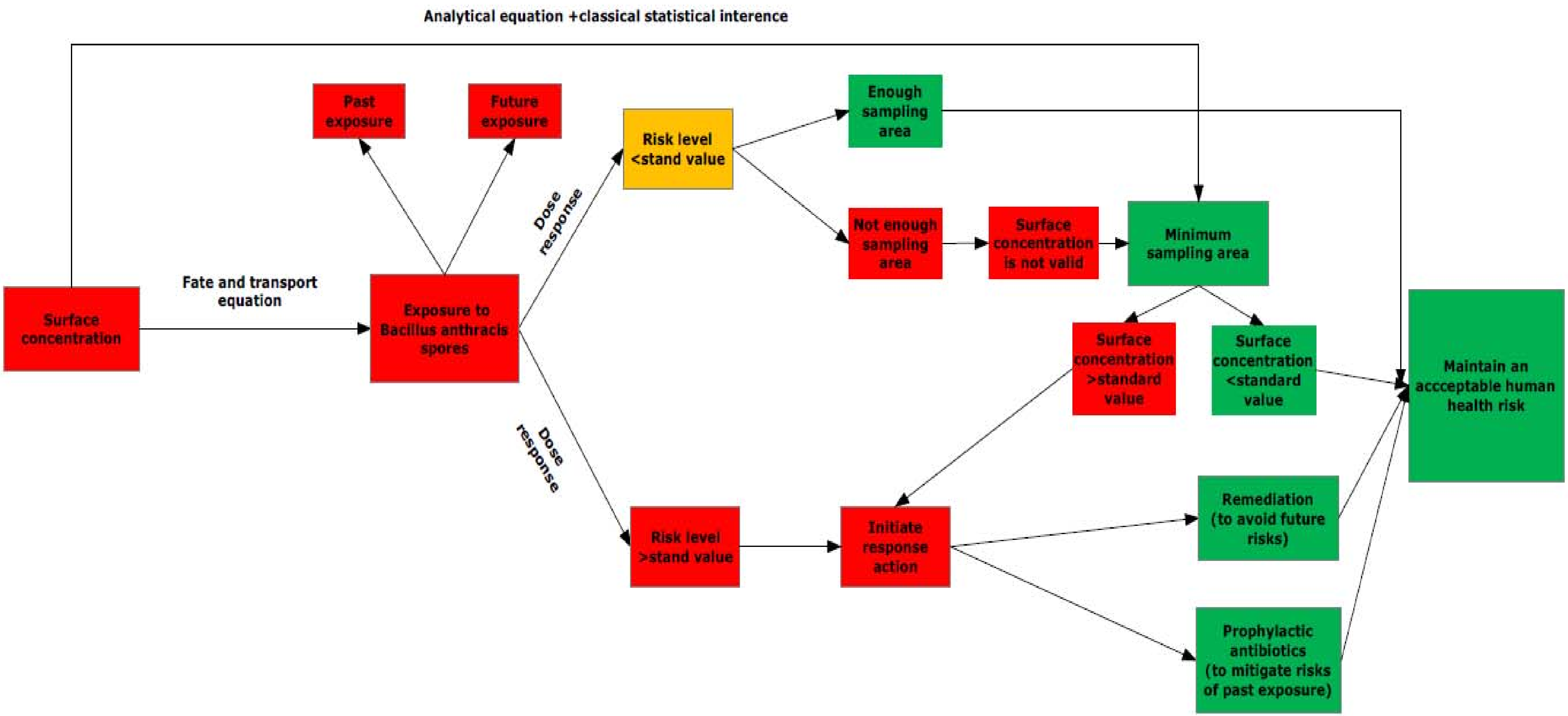
Introduction

- 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 interence
Past exposure
Future exposure
Risk level <stand value
Enough sampling area
Dose response
Not enough sampling area
Surface concentration is not valid
Minimum sampling area
Fate and transport equation
Surface concentration
Exposure to Bacillus anthracis spores
Surface concentration >standard value
Surface concentration <standard value
Maintain an accceptable human health risk
Dose response
Remediation (to avoid future risks)
Risk level >stand value
Initiate response action
Prophylactic antibiotics (to mitigate risks of past exposure)

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.

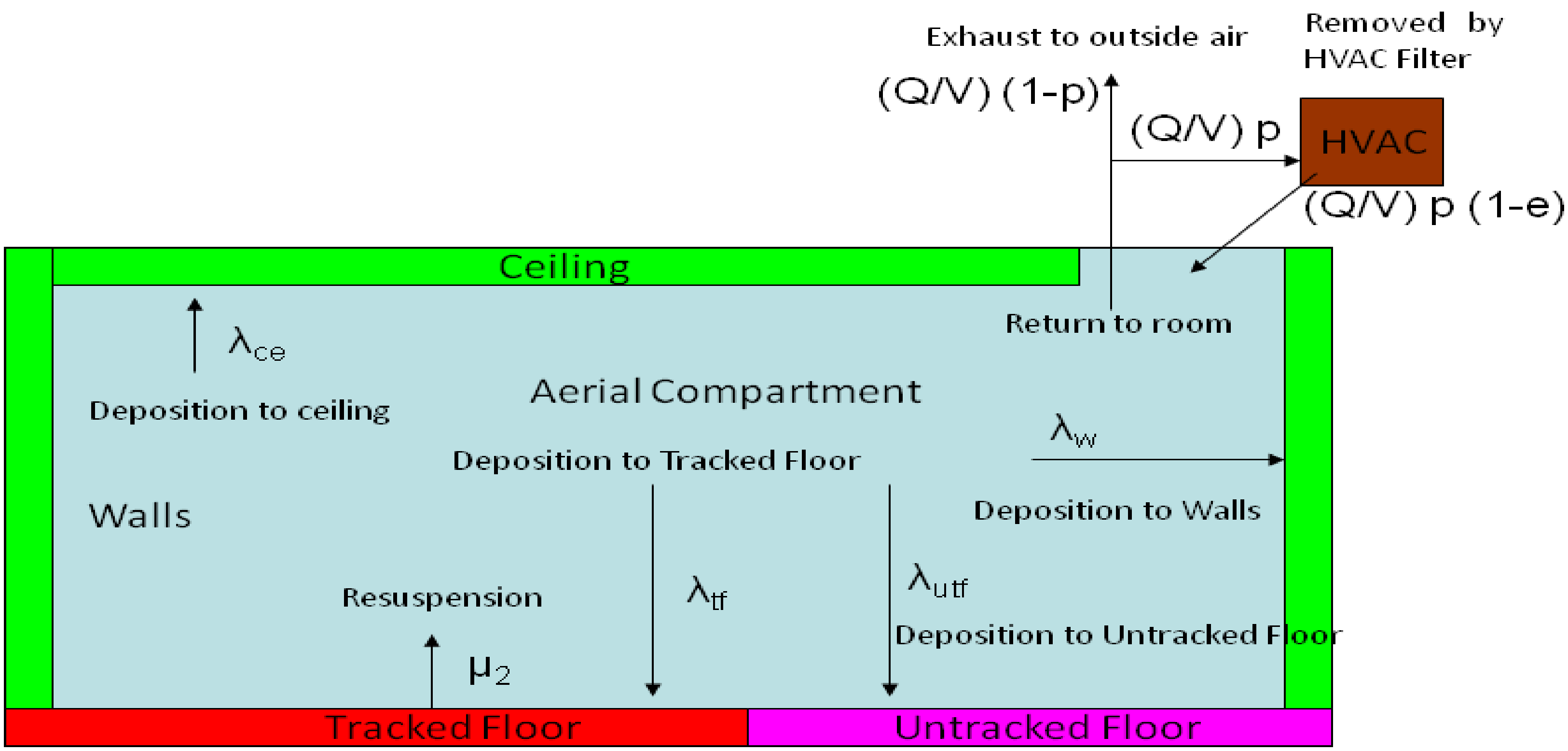
Method

- 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

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

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- α

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

- 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

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

$$f(C \quad \mid \lambda_i) = \frac{e^{-\lambda_i}\, \lambda_i^{(C \quad)}}{(C \quad)!}$$

- λ is the long run surface concentration, C is the number of counts measured on the surface
- The initial concentration prior probability f(λ_i) 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_{tf}	Area-tracked floor	m^2	5.6×5.6×0.75		
A_{utf}	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}, V_{tf}	Deposition velocity on untracked and tracked floor	m/s	1µm	3.5×10^{-5}	(Lai and Nazaroff 2000)	8.0×10^{-4}	(NRC 2005) (Riley, McKone et al. 2002)	6.9×10^{-5}
			3µm	2.0×10^{-4}	(NRC 2005)	6.0×10^{-3}		4.2×10^{-4}
			5µm	3.0×10^{-4}		1.4×10^{-2}		1.4×10^{-3}
			10µm	7.0×10^{-4}		2.7×10^{-2}		5.6×10^{-3}
V_w	Deposition velocity on walls	m/s	1µm	3.5×10^{-6}	(Lai and Nazaroff 2000)	9.0×10^{-5}	(Schneider, Kildeso et al. 1999)	3.9×10^{-5}
			3µm	1.5×10^{-6}		2.1×10^{-4}		1.6×10^{-4}
			5µm	1.0×10^{-6}		4.0×10^{-4}		3.1×10^{-4}
			10µm	7.0×10^{-9}		6.0×10^{-4}		3.5×10^{-4}
V_{ce}	Deposition velocity on ceiling	m/s	1µm				(NRC 2005)	6.2×10^{-7}
e_n	Nasal passages particle remove efficiency		1µm	0.02				
			3µm	0.22	(Landahl 1950)	0.25	(Roger O. McClellan and Henderson 1989)	0.14
						0.68		0.45
			5µm	0.42		0.81		0.62
			10µm	0.62		0.91		0.77
r	Probability of a single Bacillus anthracis spore initiating infection		1-5 µm	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^{-6}
			10 µm	1.0×10^{-7} (95% confidence interval)	Extrapolated from (Jade Mitchell-Blackwood, Patrick L. Gurian et al. 2008)	8.1×10^{-6} (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

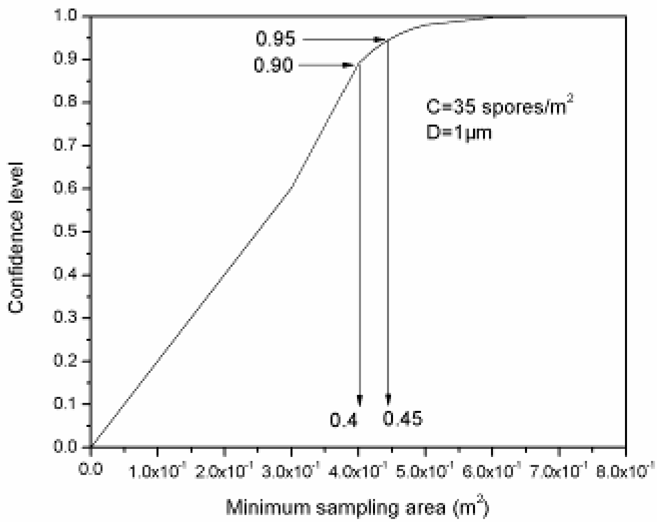
Result

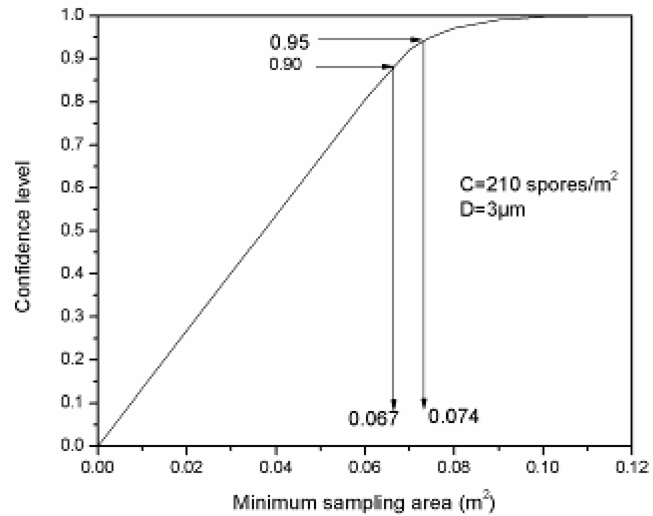
Minimum sampling area and surface concentration after a 8 hours releasing
Risk level=0.001

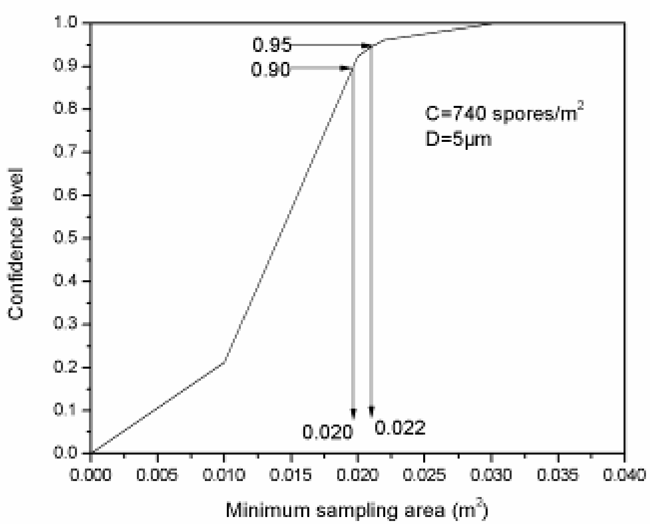
Diameter (µm)	Amount of Initial Release (Range) (spores/m²)	Untracked or Tracked floor (Range) (spores/m²)	MSA (Range) (m²)	Walls (Range) (spores/m²)	MSA (Range) (m²)	Filter (Range) (spores/m²)	MSA (Range) (m²)	Nasal Passages (spores/m²)	MSA (Range) (m²)
1	1.5×10^{4} (2.4×10^{3}–5.7×10^{5})	35 (8.8×10^{-1}–4.0×10^{3})	0.50 (4.3×10^{-3}–19)	20 (8.8×10^{-4}–4.5×10^{2})	0.84 (3.8×10^{-2}–1.9×10^{4})	8.8×10^{4} (38-1.5×10^{6})	1.9×10^{-4} (1.1×10^{-5}-4.4×10^{-1})	24 (0.36–3.4×10^{2})	0.68 (4.9×10^{-2}–47)
3	3.8×10^{4} (2.5×10^{3}–1.3×10^{6})	2.1×10^{2} (5.1–3.0×10^{4})	8.0×10^{-2} (5.7×10^{-4}–3.4)	79 (3.8×10^{-4}-1.0×10^{3})	0.21 (1.6×10^{-2}–4.5×10^{4})	4.4×10^{5} (1.9×10^{2}–7.5×10^{6})	3.7×10^{-5} (2.2×10^{-6}–8.8×10^{-2})	78 (3.9–9.3×10^{2})	0.20 (1.8×10^{-2}–4.3)
5	7.0×10^{4} (2.7×10^{3}–3.3×10^{6})	7.4×10^{2} (7.6–6.9×10^{4})	2.3×10^{-2} (2.4×10^{-4}–2.2)	1.5×10^{2} (2.5×10^{-4}–2.0×10^{3})	0.10 (8.5×10^{-3}–6.7×10^{4})	6.6×10^{5} (2.9×10^{2}-1.1×10^{7})	2.3×10^{-5} (1.5×10^{-6}–5.8×10^{-2})	108 (7.5–1.1×10^{3})	0.14 (1.5×10^{-2}–2.3)
10	1.3×10^{6} (2.6×10^{4}–6.4×10^{7})	2.6×10^{4} (1.5×10^{2}-1.2×10^{6})	6.5×10^{-4} (1.4×10^{-5}-0.1)	1.5×10^{3} (1.5×10^{-3}–2.7×10^{4})	1.0×10^{-2} (1.4×10^{-5}–1.1×10^{4})	6.9×10^{6} (3.0×10^{3}-1.2×10^{8})	2.2×10^{-6} (1.4×10^{-7}–5.7×10^{-3})	1.2×10^{3} (96–1.1×10^{4})	1.3×10^{-2} (1.5×10^{-3}–0.18)

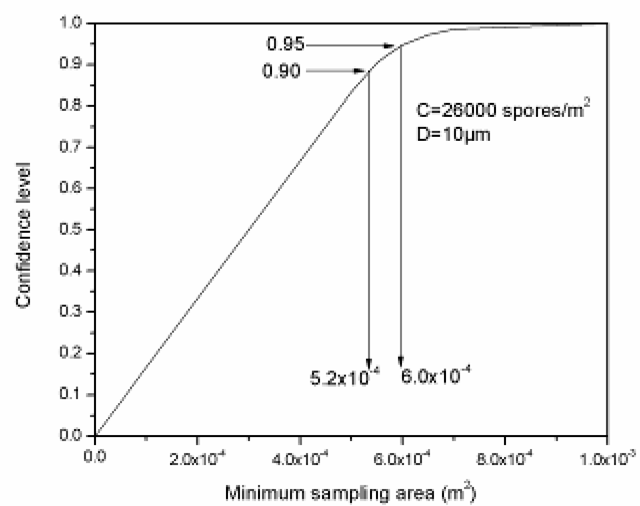
MSA is computed based on the 95% confidence interval, and A $C_{stan}\geq16.96$

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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