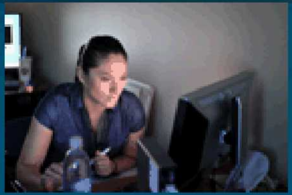
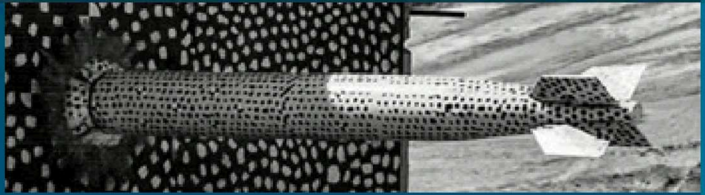
SAND2018-13105C

Particle Resuspension and Its Relation to Radiological Risk





PRESENTED BY

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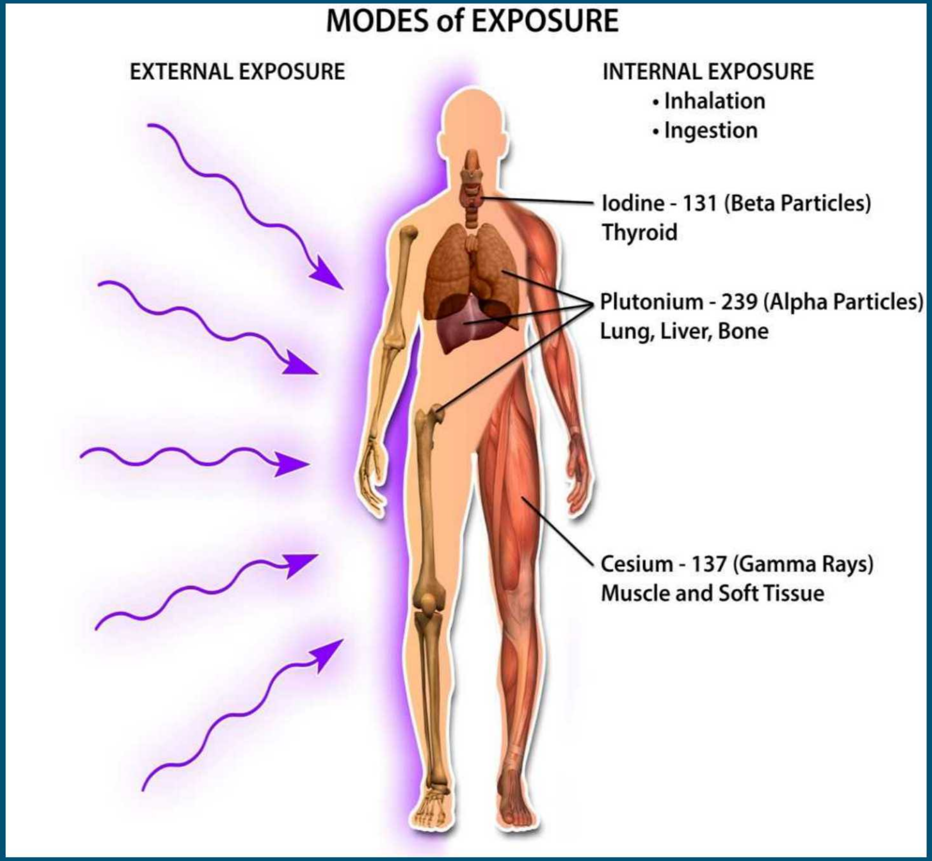
A proper understanding of resuspension is important to understanding the true consequence of the radiological dispersal of an alpha-emitter.

Internal doses are obtained from radionuclides taken into the body.

Internal dose projection calculations are dependent on body models and aerosol properties.

External dose projection calculations are independent of these.

Internal dose tends to be limiting for alpha-particle emitting radionuclides.



Airborne particulates deposit and cause internal dose.

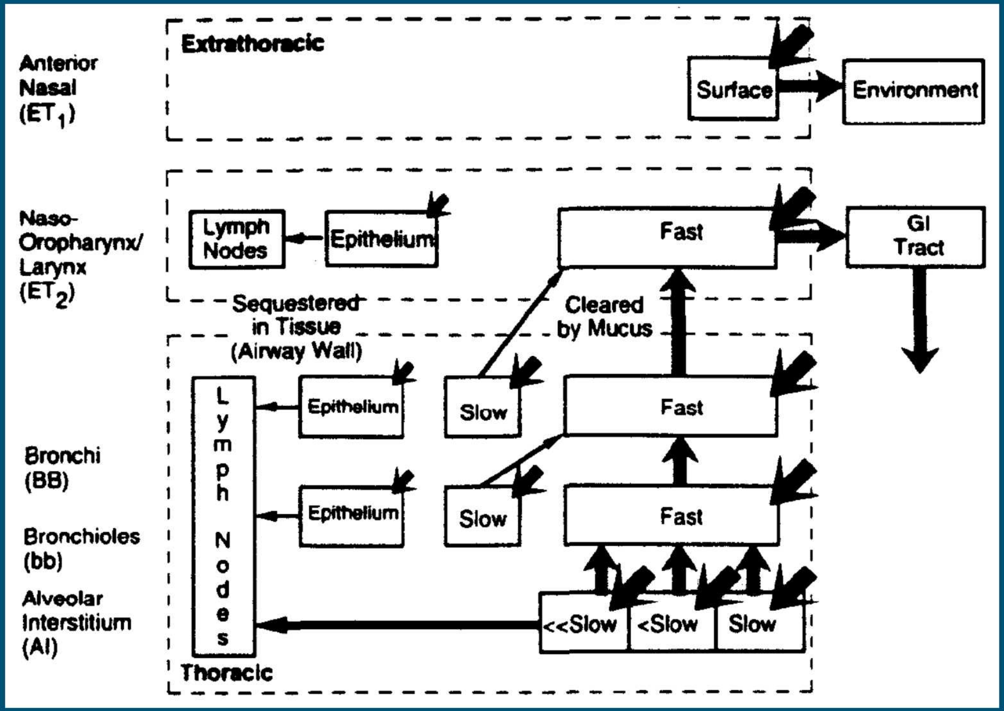
Particulates deposit in regions of the respiratory tract dependent on their particle size.

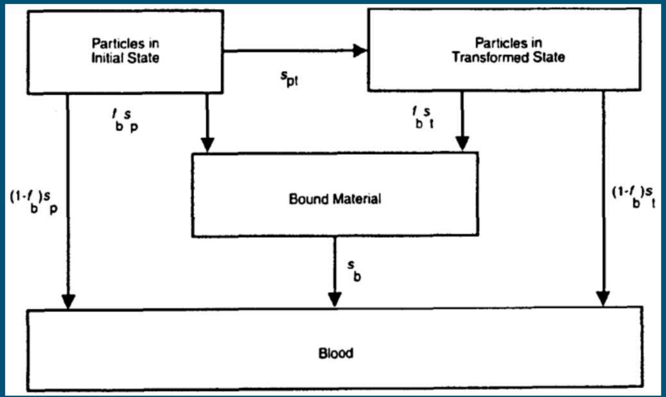
Deposited material is removed from the lung through two mechanisms:

- Clearance: mechanical removal upwards and swallowed
- Absorption: dissolution and movement into the bloodstream

432 year radiological half-life and long biological retention means dose will be received over lifetime.

- Alpha particles deposit large amounts of energy (5.4 MeV) in small volume.
- Dose is accumulated over 70 years to meet 0.02 Sv threshold





IAEA “D-values” are based on radiation safety scenarios.

The IAEA published “D-values” for source protection considerations in 2006.

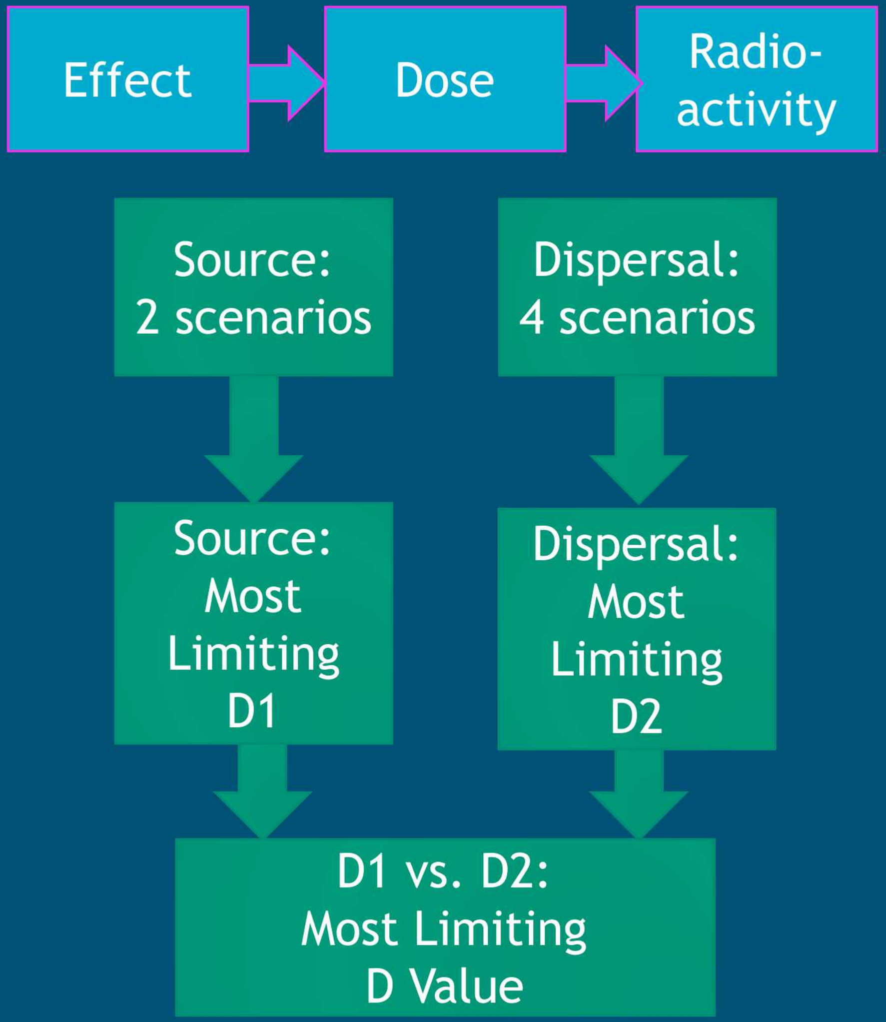
Evaluations were made to deterministic effects:

- “Fatal effects are those that, if developed, lead to death”
- “Non-fatal effects are those that reduce the quality of life and are organ or tissue specific”

D1 – non-dispersal scenarios (271)

D2 – dispersal scenarios

- “inhalation” – fire or explosion (65)
- “ingestion” – leaking source or water contamination (1)
- “contamination” – leaking source on skin (8)
- “immersion” – noble gases (0)



A purposeful dispersion includes groundshine and resuspension.

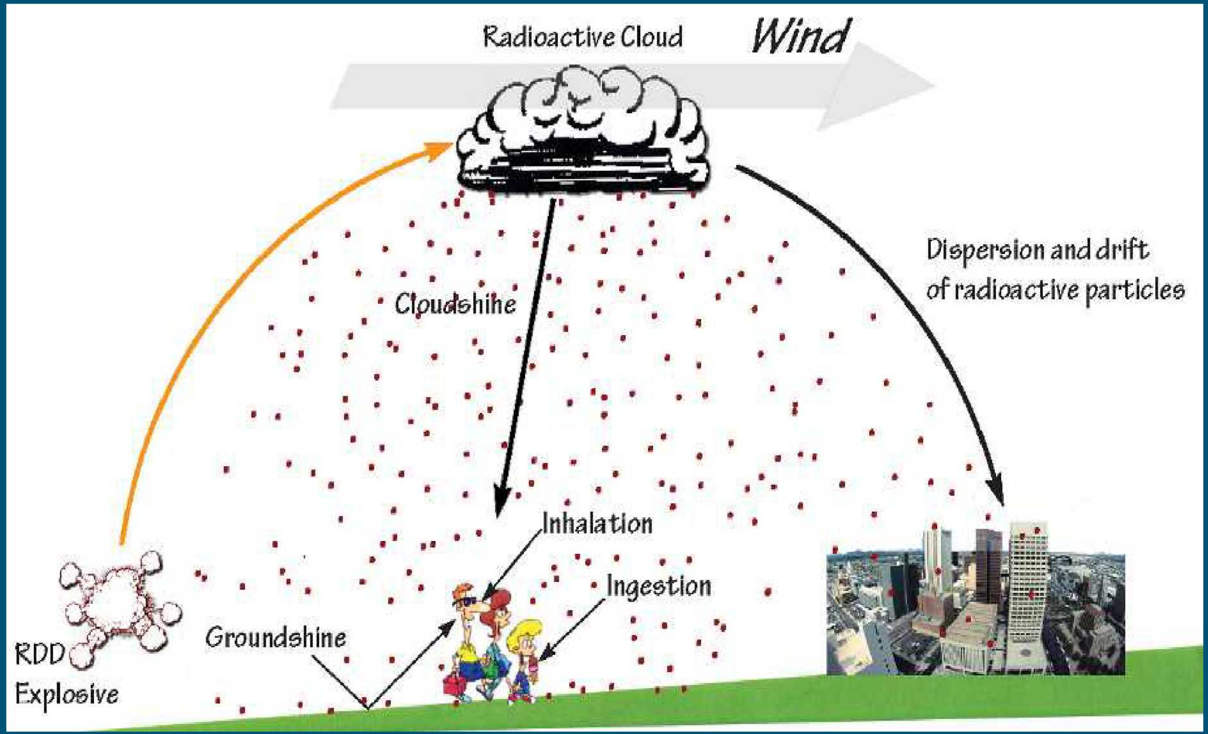
Plume passes during the first few days following dispersal.

- "Cloudshine" (scenario VI)
- "Inhalation" (scenario I)

Without relocation, exposure to population continues.

- "Groundshine" – dominates for β/γ
- "Resuspension" – dominates for α

Resuspension is expressed in terms of airborne concentration: (activity/m^3) / (activity/m^2).



The “power to contaminate” considers both groundshine and resuspension doses.

Power to Contaminate (PTC): amount of material (radioactivity) that, if uniformly spread over 1 km^2 would cause a dose to an individual constantly exposed in the first year following dispersion of 20 mSv.

20 mSv is the USEPA “protective action guide” for relocation

	PTC (TBq)	Cat 2 (TBq)	Pathway
^{137}Cs	1.6	1	groundshine
^{60}Co	0.4	0.3	groundshine
^{192}Ir	3.7	0.8	groundshine
^{241}Am	0.15	0.6	resuspension

Concentration of airborne particulates is defined by resuspension.

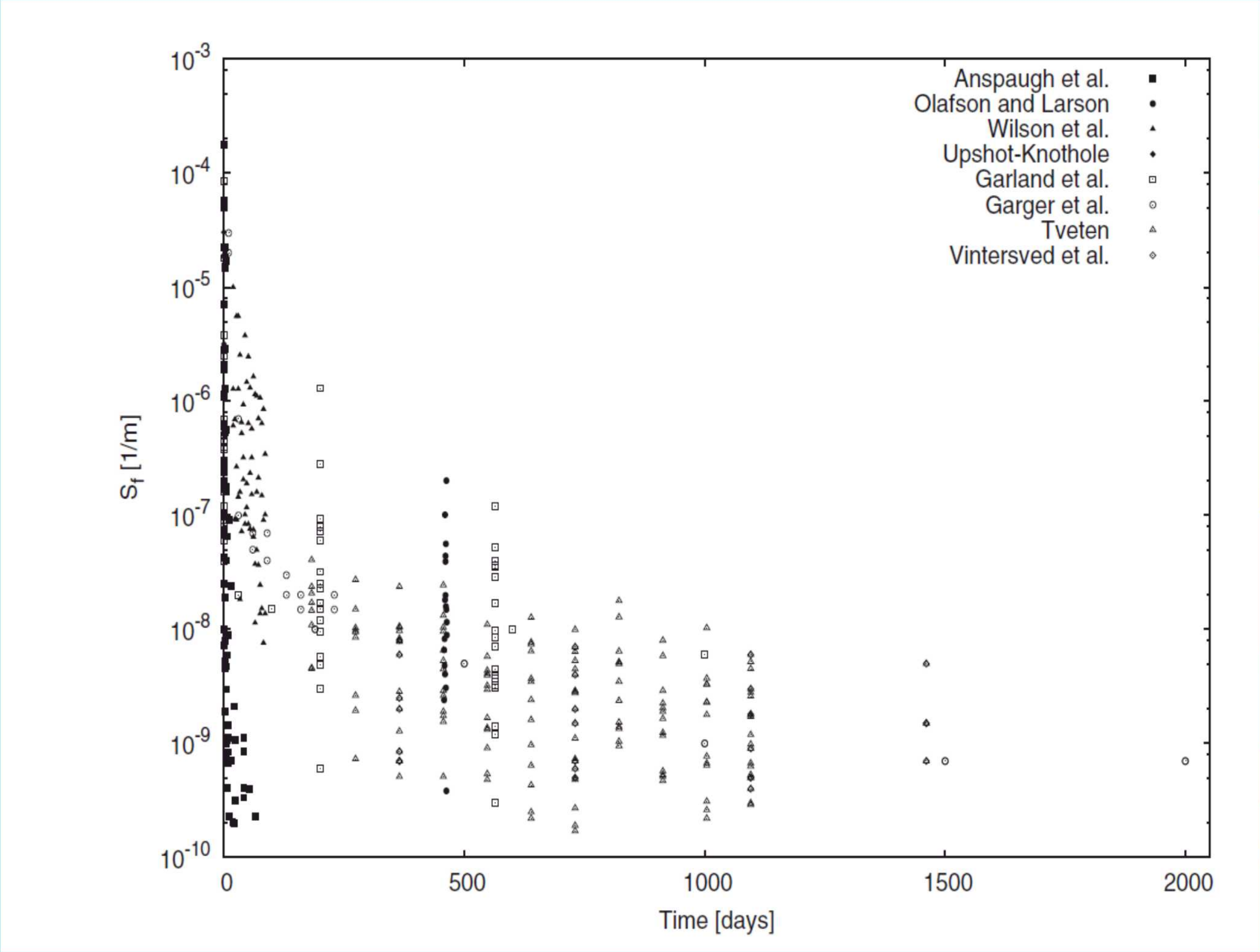
Resuspension is expressed in terms of airborne concentration (act/m^3) / (act/m^2)

Data has been collected from multiple sources:

- Chernobyl
- Wind tunnel studies
- Nuclear weapons testing

No consideration for:

- Element and associated chemistry
- Ground substrate properties
- Particle size of dispersed material
- Particle size of resuspended material



The uncertainty in the data set leads to varied mathematical functions.

Fits that are visibly different can still be considered "right."

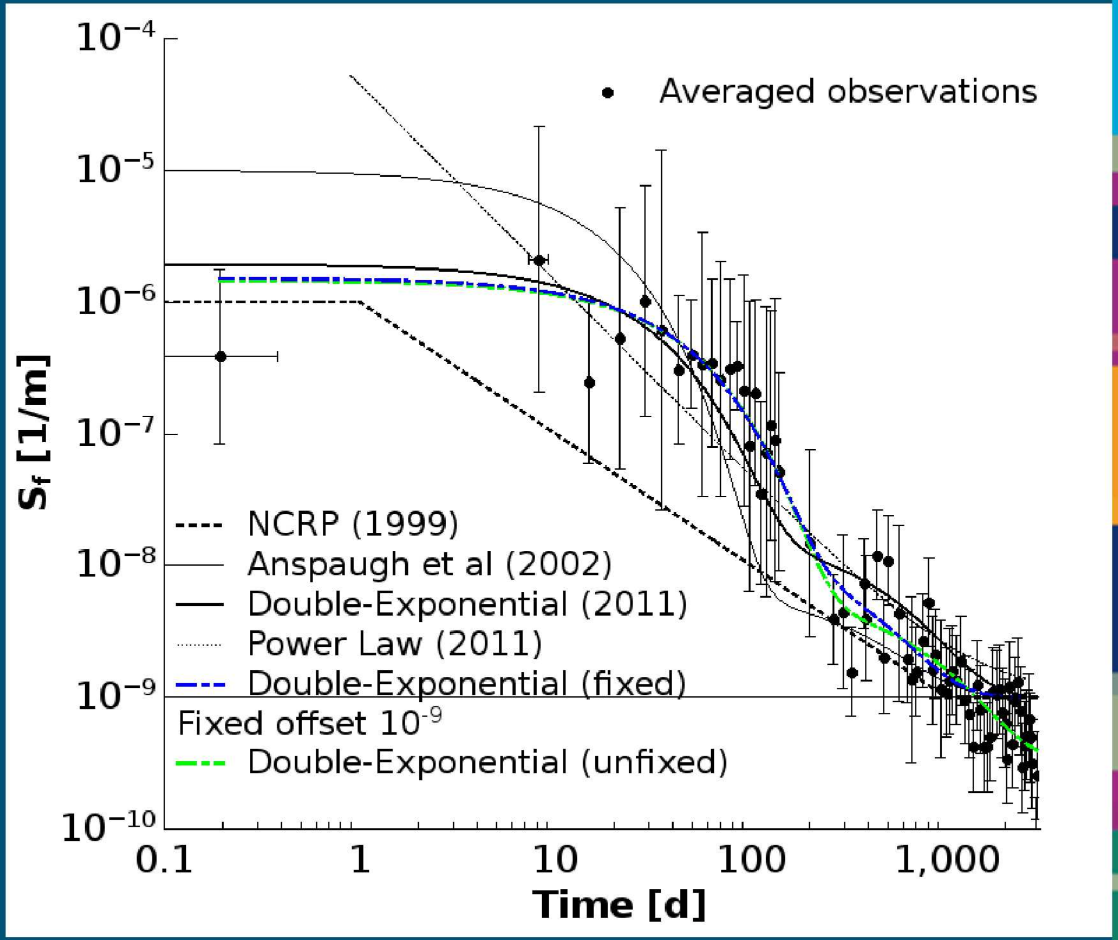
Observations:

- Double-Exponential 2011 fit favored large/high data values
- NCRP-129 underestimated resuspension for first 100s of days
- Removing offset appears to improve fit
- Data shows two functions with a cutoff at 200 days.

WPI approach "binned" the data and used the uncertainties in the bins to "weight" each data point.

The double-exponential (fixed) function results in a PTC of 0.4 TBq (vs. 0.15 TBq from D-E 2011).

Where does "suspension" end and "resuspension" begin?



Experiments were designed to measure resuspension in an ^{241}Am surrogate (Eu).

A known mass of non-radioactive Eu_2O_3 surrogate (a chemical analog to Am_2O_3) was deposited on a substrate

Neutron activation analysis was used to quantify Eu on filter, which allowed us to calculate resuspension.

Experiments were conducted at Worcester Polytechnic Institute

Resuspension chamber with vacuum pump head.

WPI D-D neutron generator

WPI BEGe detector

Experimental results showed lower than expected resuspension.

Data collected at 1–7 days.

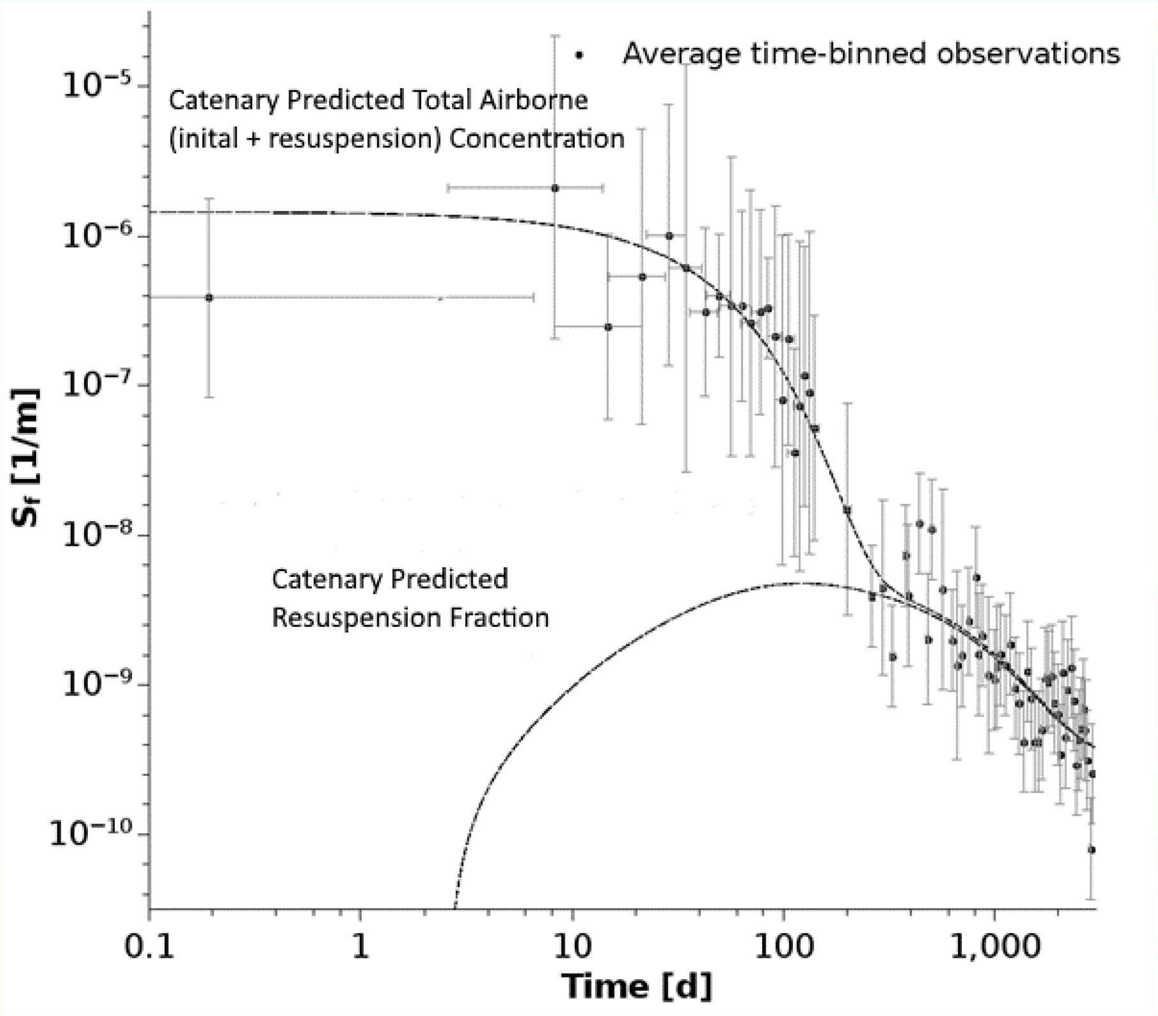
Results were unexpectedly below detection limits at or below 1×10^{-9} m^2/m^3.

This would occur if the airborne concentration began at zero (as designed) and increased with time.

- The question then is, what are the early measurements?

A transitional model may explain.

- Early (1–100) day measurements may include "suspended" and "transitionally resuspended" material.



A proper understanding of resuspension is important to understanding the true consequence of a radiological dispersal of an alpha-emitter.

The resuspension research provided insight and scope to the problem:

Variability and inability to repeat results in historical data makes proper fitting to a model difficult.

- WPI's approach provided a better result in terms of a fit line generally through the middle of the data.
- PTC using WPI's fit equation is 9.9 Ci.

Resuspension at days to weeks following dispersion includes mechanisms not properly described in existing models.

- There is likely a transitional phase where particulates are neither fully airborne or completely deposited.
- Chemical interactions between the dispersant (Am) and the substrate (ground material) could play a role.

Particle size of resuspended material must also be considered.

- The amount of material deposited in the lung and available for dose to lung tissue and absorption is dependent on the particles' size.