UNIVERSITY OF CALIFORNIA

UC CEIN Center for Environmental Implications of Nanotechnology

Modeling Indoor Occupational Air Exposure to Nanomaterials for Life-Cycle Assessment

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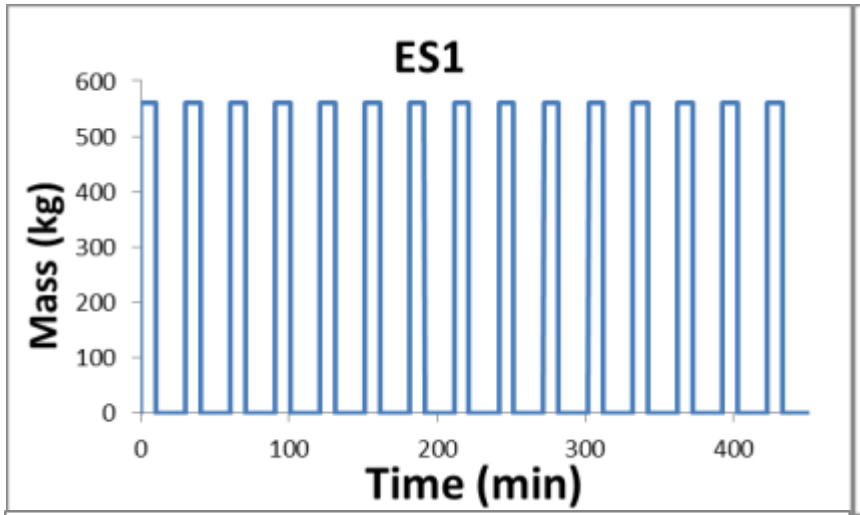
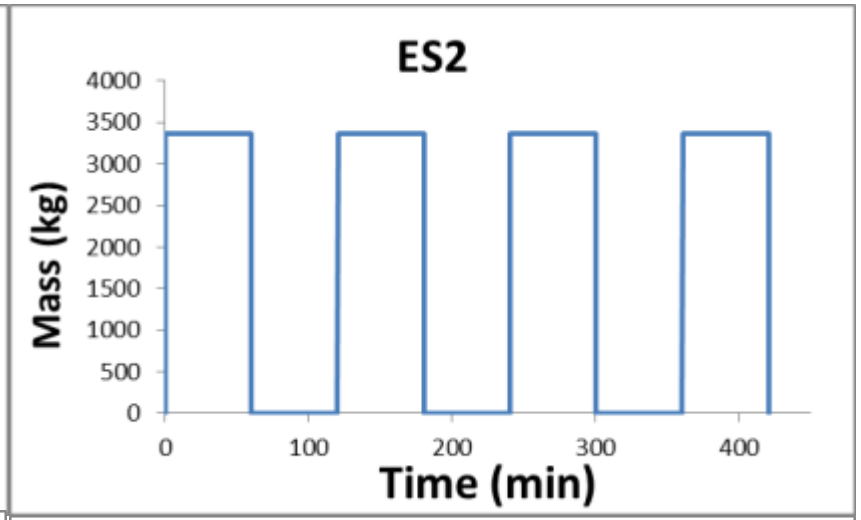
Objectives

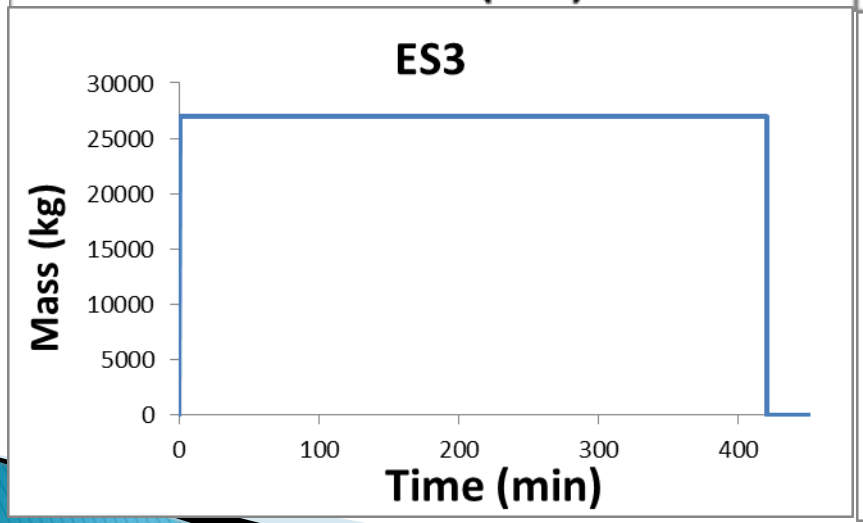
- Predict ENM exposure in occupational settings
- Occupational settings present scenarios where emissions of pristine particles with small size distributions may occur
- Consider different exposure scenarios
- Relate to potential effects

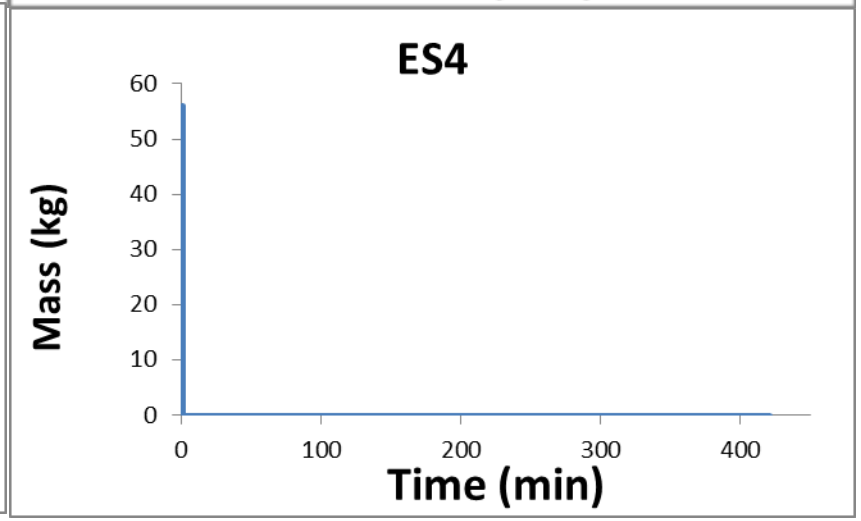
Exposure Scenarios

Adapted from NANEX (www.nanex-project.eu) database



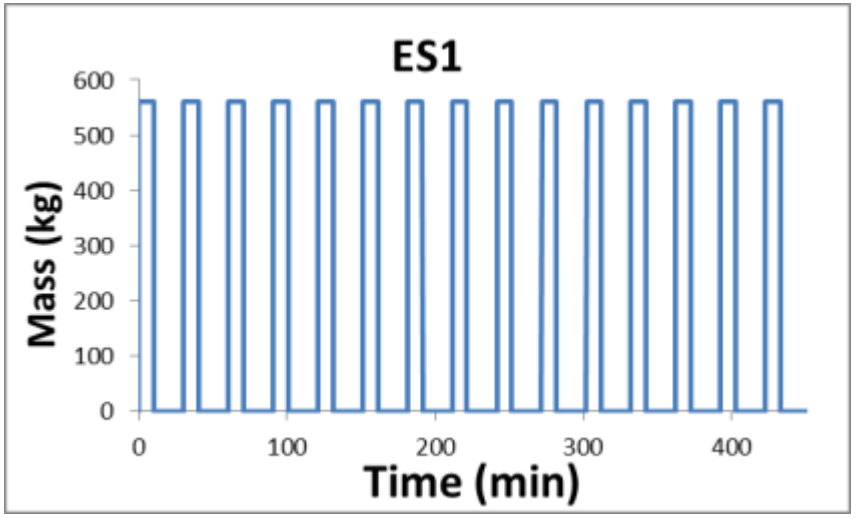


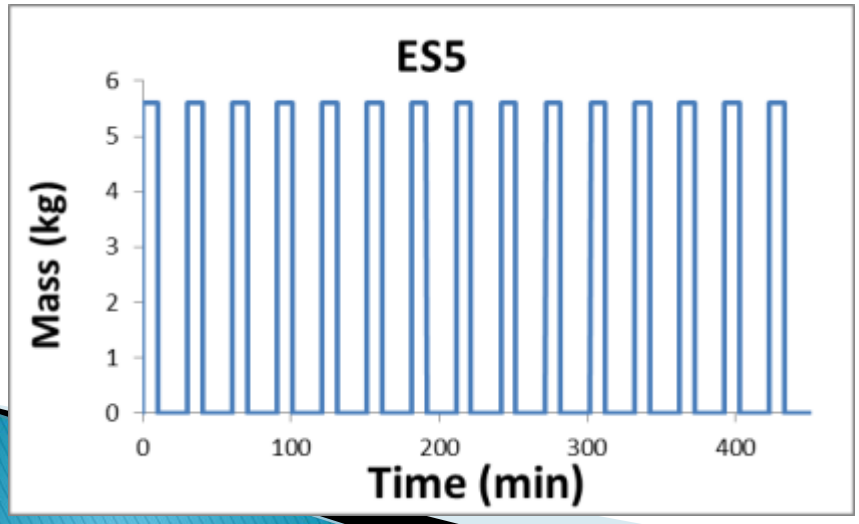


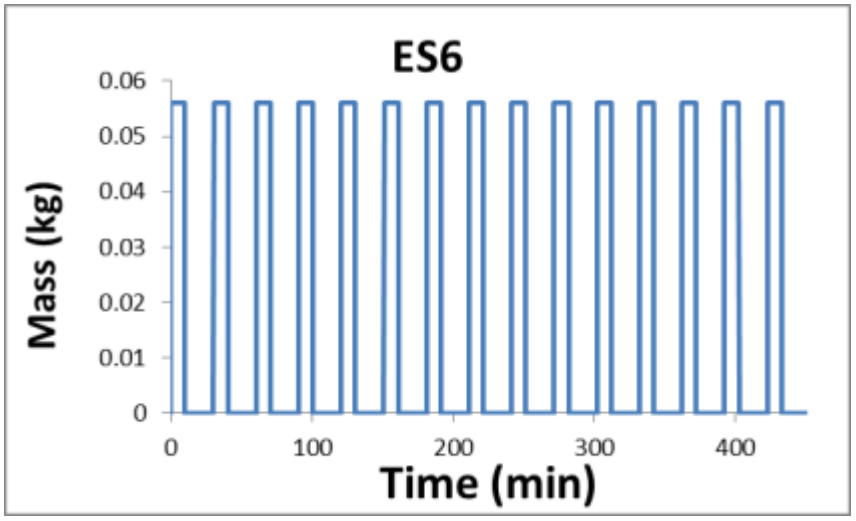


Exposure Scenarios

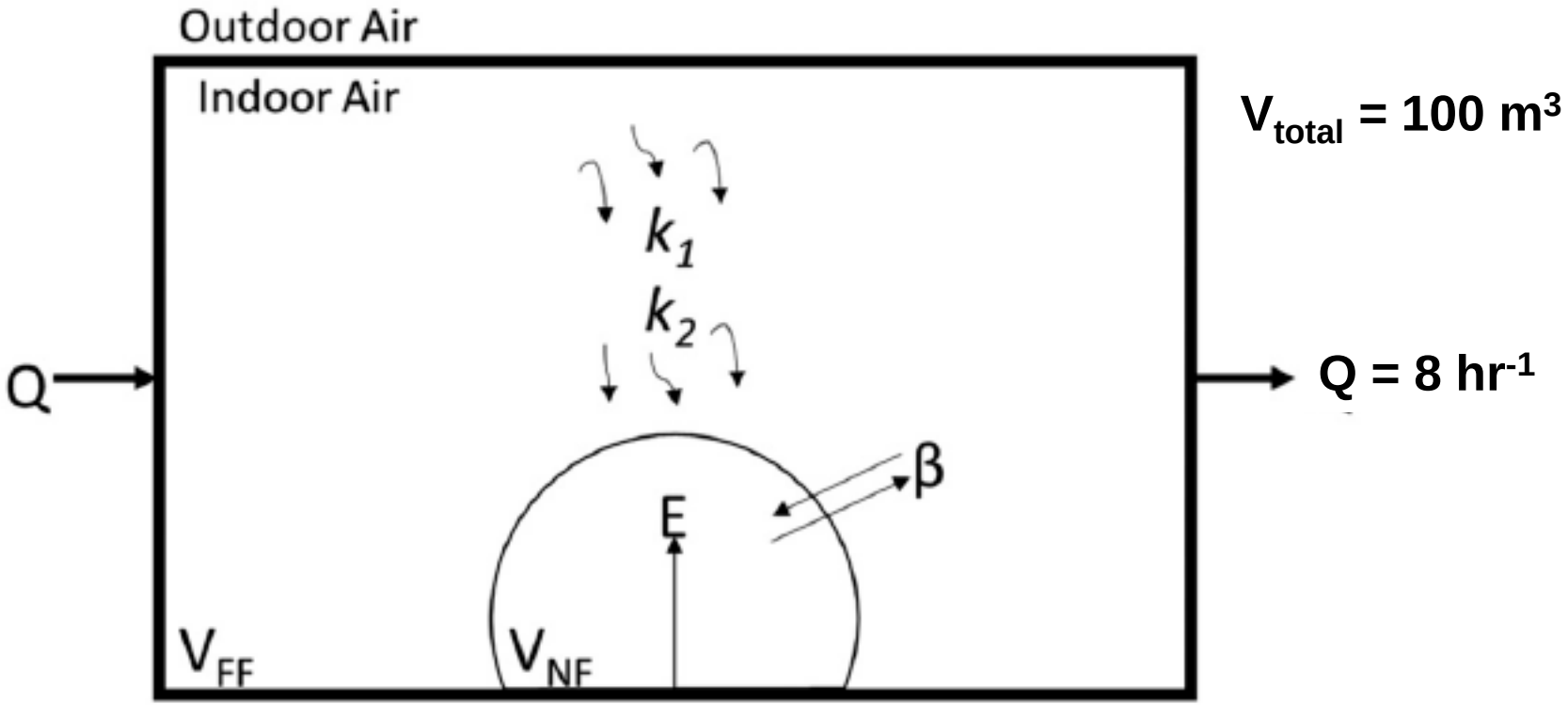
- Same pattern, different amounts handled
- ES1 factory setting
- ES5 large lab
- ES6 small lab







Conceptual Model



Fate and Transport of Airborne $nTiO_2$

- Two zone model
  - Near-field (close to handling area): C_{NF}
  - Far-field (other side of room):C_{FF}

- $V_{NF} \cdot \frac{dC_{NF}}{dt} = S + (\beta \cdot C_{FF-1}) - (\beta \cdot C_{NF-1}) - (C_{NF-1} \cdot V_{NF} \cdot \sum k_i)$

- Change NF = source ± exchange NF-FF – losses (deposition)

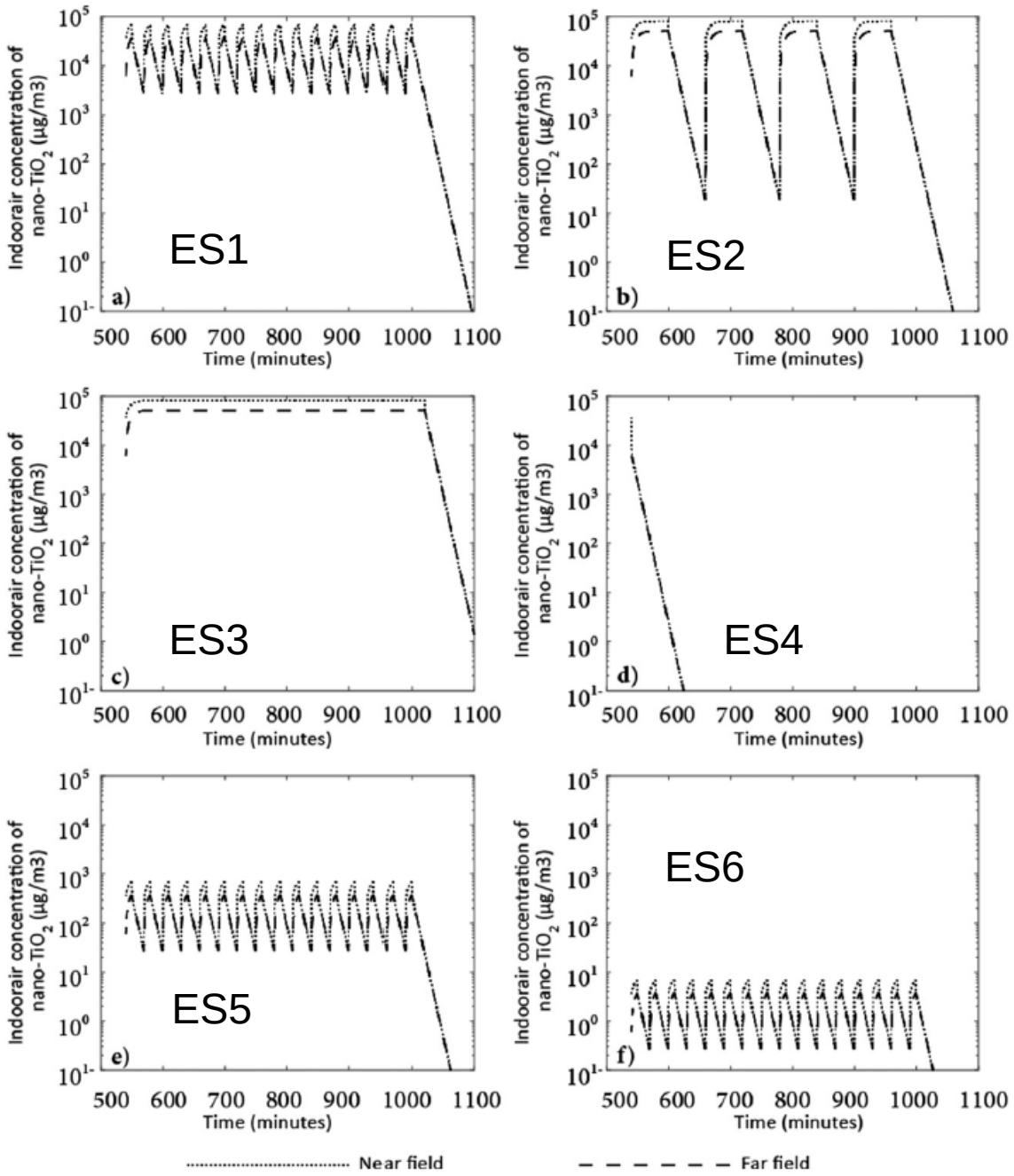
- $V_{FF} \cdot \frac{dC_{FF}}{dt} = (\beta \cdot C_{NF-1}) - (C_{FF-1} \cdot V_{FF} \cdot \sum k_i) - ((\beta + Q) \cdot C_{FF-1})$

- Change FF = From NF – losses – exchange to NF or out (Q)

- Q = ventilation rate
- Deposition based on Stokes' Law

Exposure concentrations

	$C_{NF,max}$ (mg/m^3)	$C_{FF,max}$ (mg/m^3)	$C_{NF,avg}$ (mg/m^3)	$C_{FF,avg}$ (mg/m^3)
ES1	65.00	34.50	24.90	14.80
ES2	81.50	50.90	40.70	25.40
ES3	81.50	50.90	80.80	50.20
ES4	36.30	6.01	0.17	0.11
ES5	0.68	0.37	0.27	0.17
ES6	0.01	0.004	0.003	0.002



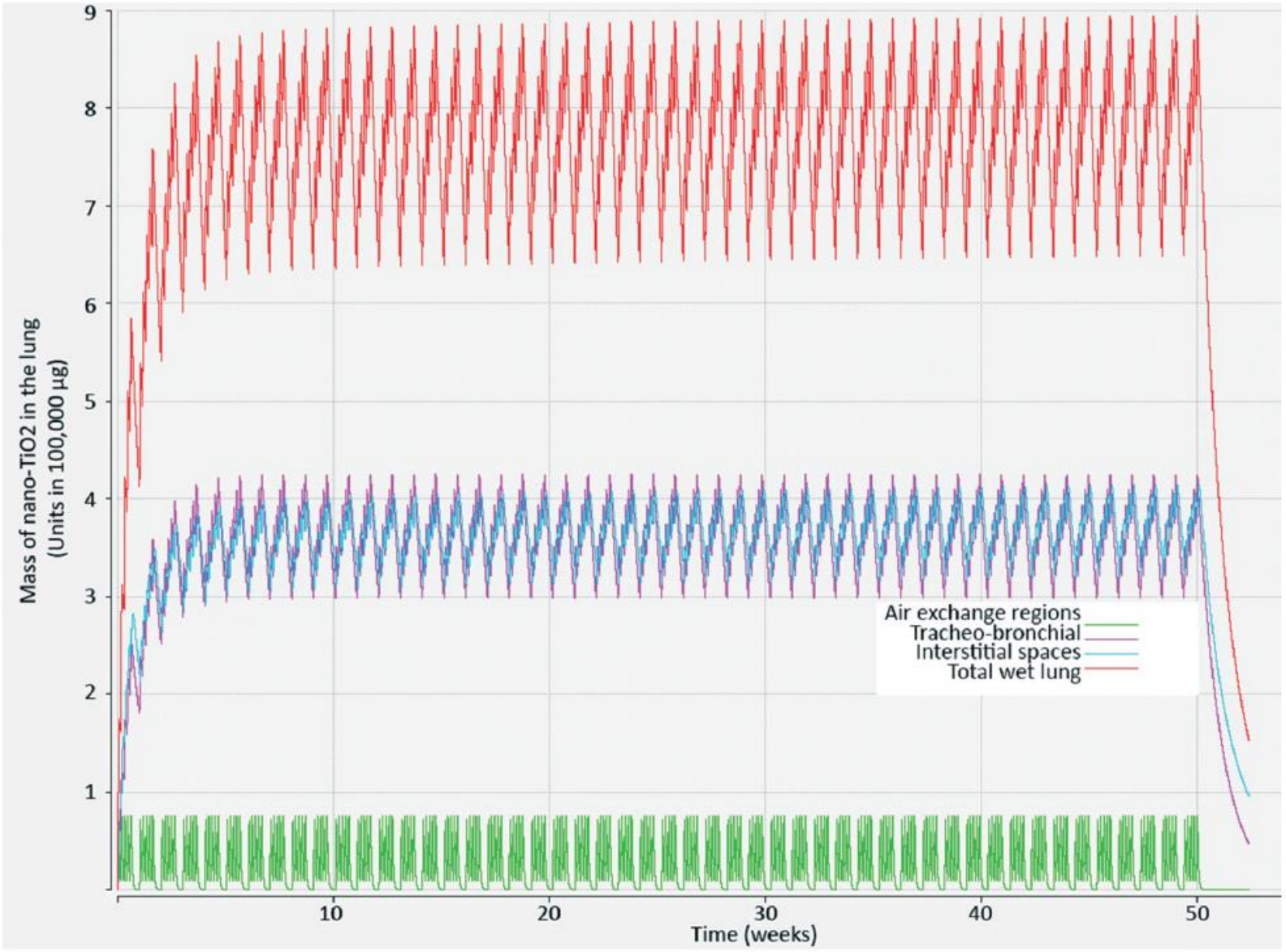
Retained-Intake Fraction of Nano-TiO_2

- Model assumes
  - No use of personal protective equipment
  - Direct interaction between the airways and indoor air

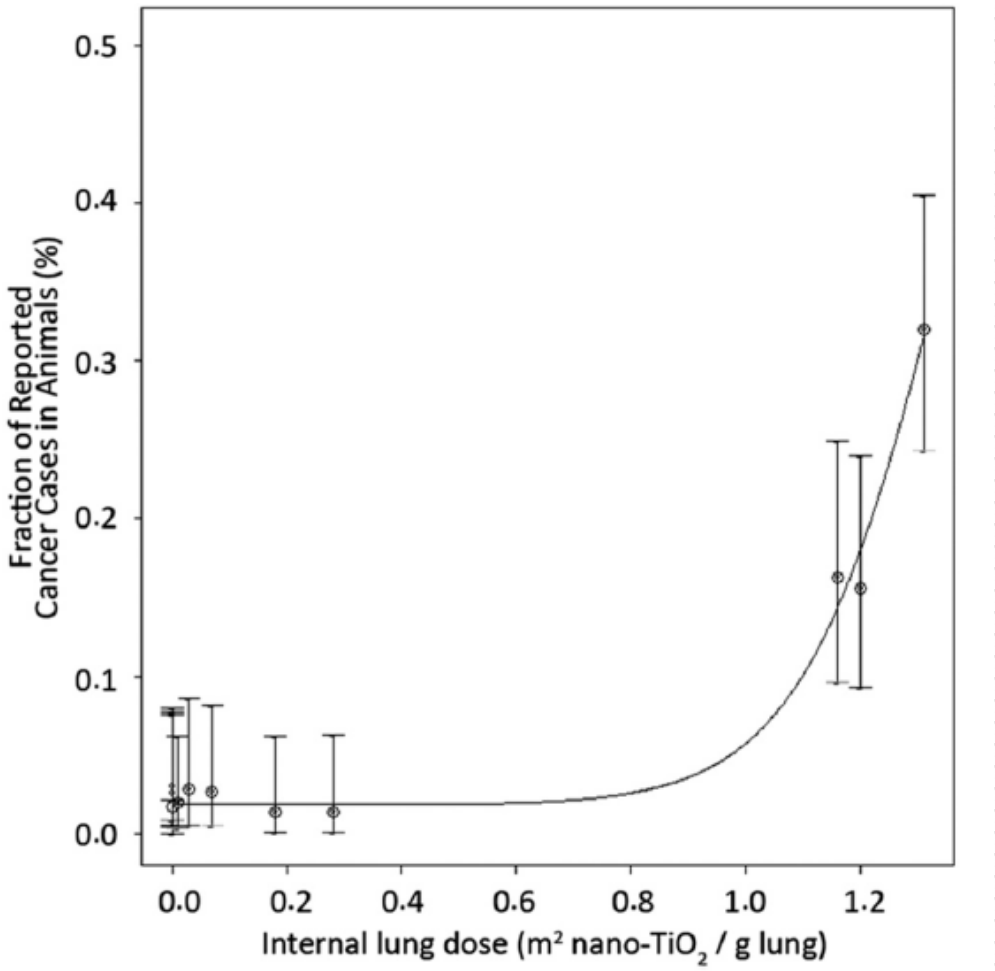
- $RiF = \frac{EXP_{\text{int}}}{E_{\text{life}}} \cdot POP$

- Retained = (exposure/lifetime exp) x population
- Lifetime exposure:
  - 1-year (short-term)
  - 45-year (chronic)

Retention of $nTiO_2$ in lung over 1 work year for ES1



Dose-response for $nTiO_2$: lung cancer



- Exposure in surface area of $nTiO_2$ per g dry lung
- Based on rat studies
- Inhalation is the only pathway

Dose-response for $nTiO_2$: non-cancer effects

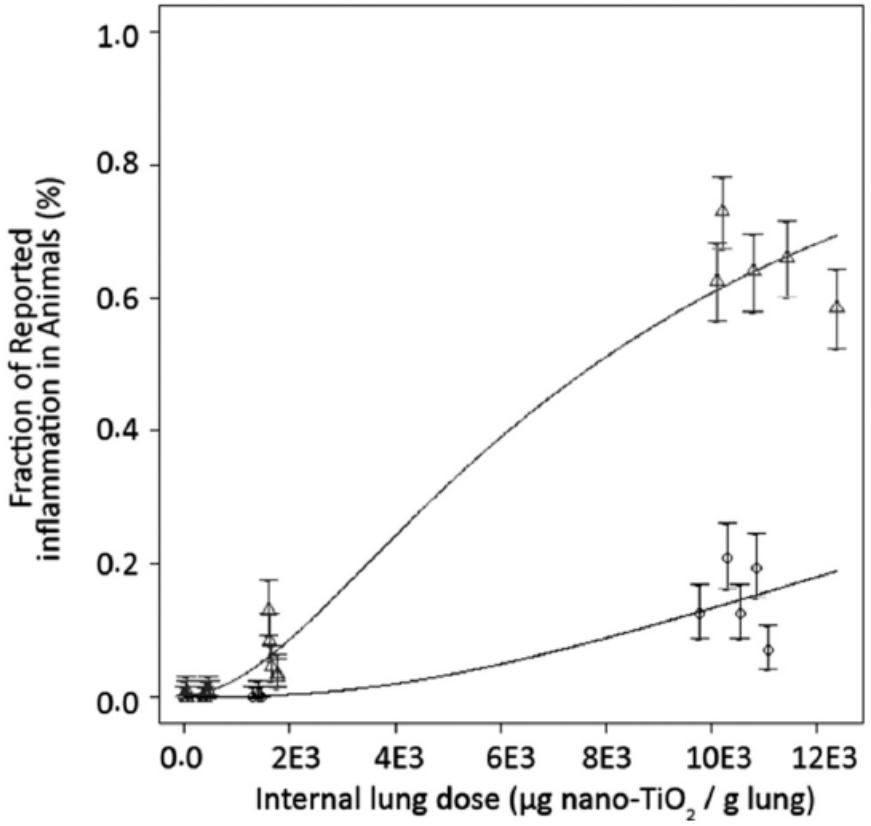


Fig. 8 Benchmark dose results for non-cancerous impacts to both mice (circles) and rats (triangles).

- Inflammatory response
- Mice and rat studies show significant differences in response
- Since rats were more sensitive, this data was used as proxy for effects on humans

Risk Characterization

	1-year		Lifetime	
	CF_{Cancer}	$CF_{Non\text{-}cancer}$	CF_{Cancer}	$CF_{Non\text{-}cancer}$
ES1	8.31E-05	3.17E-05	3.96E-04	1.51E-03
ES2	1.12E-05	4.29E-05	5.35E-04	2.04E-03
ES3	1.21E-05	4.62E-05	5.75E-04	2.19E-03
ES4	3.34E-05	1.27E-04	1.63E-03	6.24E-03
ES5	2.42E-05	9.23E-05	1.18E-03	4.48E-03
ES6	2.47E-06	9.44E-06	5.80E-05	2.21E-04

- Risk does vary based on exposure scenario
- Lifetime exposure significantly increases risk
- Better info needed to characterize hazard

Conclusions

- Dynamic model developed for estimating exposure and risk associated with ENMs in occupational environments
- Occupational exposure will be episodic and nature of exposure needs to be taken into account
- Health risk can be significant, particularly for lifetime exposure and prolonged daily exposure
- Use of PPE can significantly reduce risk

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