A Personal Nanoparticle Respiratory Deposition (NRD) Sampler

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Background

Size-selective samplers (e.g., respirable samplers) collect particles with efficiencies to match how particles enter into the respiratory system. However, when aerosols include both nanoparticles and respirable particles, the mass measured using a respirable sampler will be dominated by the larger, non-nanoparticles.

Nanoparticles may deposit in all regions of the respiratory system, however, there is no available sampling criterion specific for nanoparticles.

A personal sampling method that removes larger respirable particles and only collects nanoparticles would streamline exposure assessments. An ideal sampler would be portable, allow placement within the breathing zone of a worker, and collect nanoparticles in a way that mimics their respiratory deposition.

Objectives

1) Develop a nanoparticulate matter (NPM) sampling criterion to provide a target collection efficiency for nanoparticles
2) Develop a personal nanoparticle respiratory deposition sampler that selectively collects nanoparticles apart from larger particles

Methods

Evaluation of Impactor Performance
- Measure the concentration by size of polydisperse NaCl aerosol before (C_{in}) and after (C_{out}) the impaction stage
- Calculate collection efficiency as $E = 1-(C_{out}/C_{in})$

Evaluation of Impactor Performance after Loading
- Load the impaction plate with 3 mg/m^3 of fine test dust for 4 hrs (12 mg/m^3 × hr) and 8 hrs (24 mg/m^3 × hr)
- Repeat impactor performance evaluation tests and calculate efficiency after loading

Effective Deposition to the Screens of the NRD Sampler
- Feed monodisperse (20-500 nm) ammonium fluorescein aerosol in a chamber containing the NRD sampler and a filter cassette with 2 Durapore membrane filters
- Recover fluorescent material from Durapore filters (M_F) and diffusion stage screens (M_D) by ultra-sonicating in ammonium hydroxide
- Measure mass concentration of fluorometric material in recovered solution using a fluorometer
- Calculate effective deposition of diffusion stage as $D_D=M_D/M_F$

Results

Nanoparticulate Matter (NPM) fraction for a given particle diameter is the fraction of those particles smaller than 300 nm that, when inhaled, can deposit in the respiratory system.

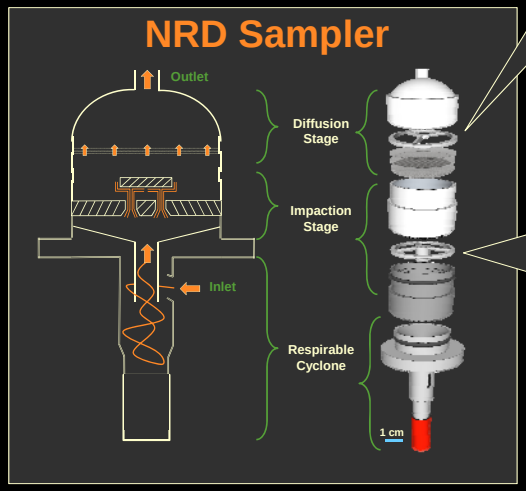
$$NPM(d)=IPM(d)[1-F(x)]$$

$$IPM(d)=0.5[1+\exp(-0.06\,d)] \quad \text{for} \quad 0 < d \le 100\ \mu m$$

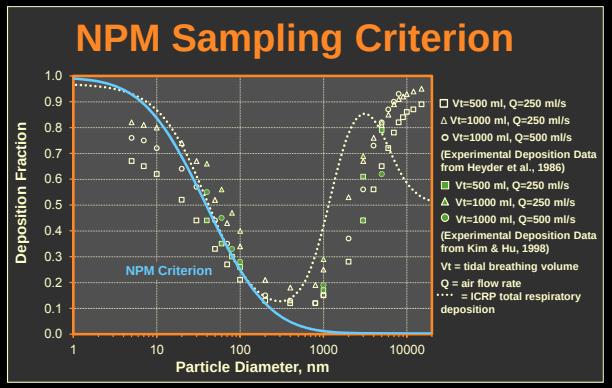
$F(x)$ is the cumulative probability density function of the standardized normal variable x,

$$x = \frac{ln(d/\Gamma)}{ln(\Sigma)}$$

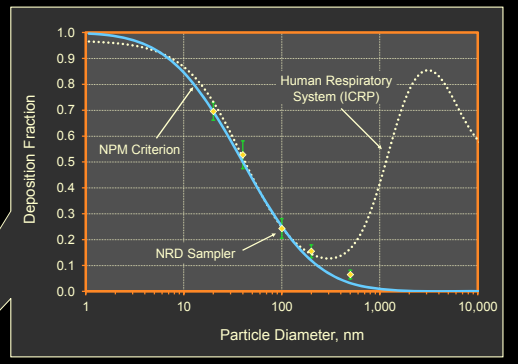
d = particle diameter
Γ = 0.04 µm (40 nm)
Σ = 3.9



Schematic (with Illustrated Flow Patterns) and Components of NRD Sampler

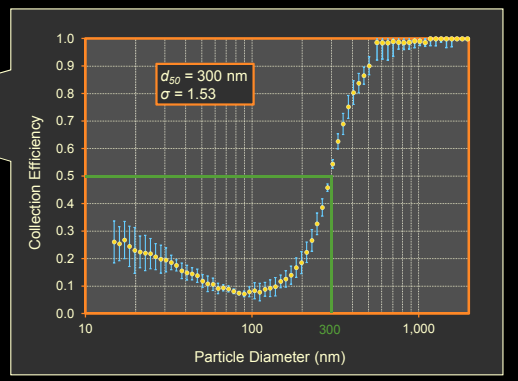


Rationale for the NPM Sampling Criterion



NPM Sampling Criterion and Particle Deposition (Human and NRD Sampler Diffusion Stage)

Nanoparticle deposition onto the diffusion stage is in agreement with the NPM sampling criterion.



Impaction Stage Collection Efficiency by Particle Size

The effect of impaction plate loading is negligible (p = 0.257) at typical workplace concentrations.

Discussion and Conclusions

- NRD sampler is lightweight (~60g) and collects nanoparticles similar to respiratory tract deposition
- Pressure drop of NRD sampler permits operation with conventional, belt-mounted sampling pumps
- Chemical analysis of diffusion media allows direct assessment of exposure to nanoparticles of specific composition apart from other airborne particles

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