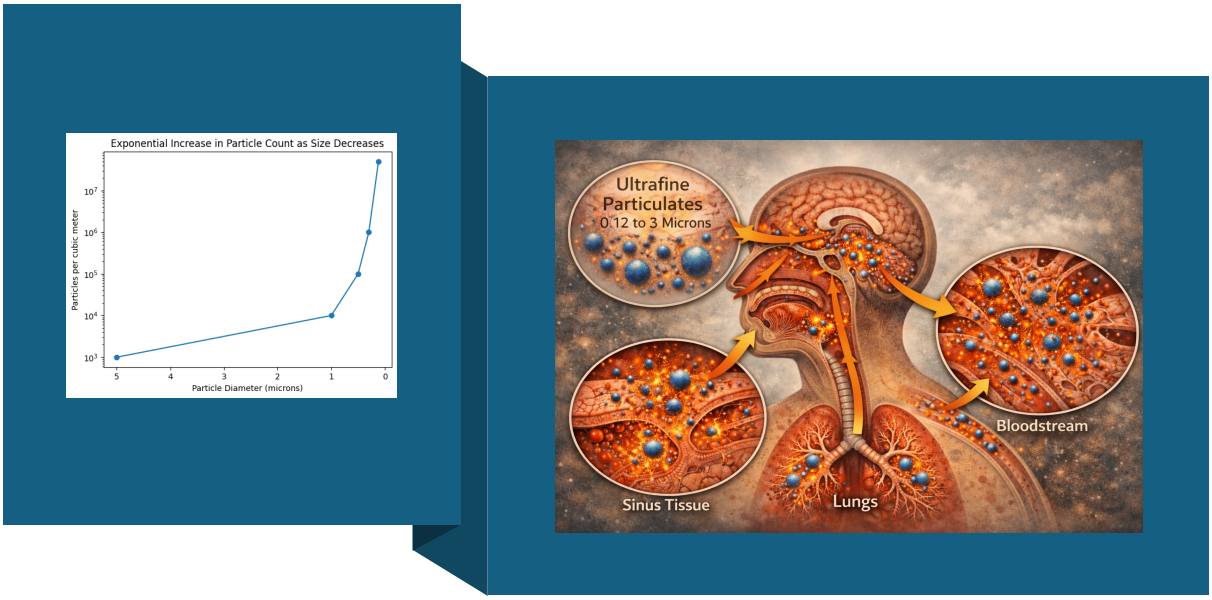
Beyond HEPA: Part II

The 0.12–0.3 Micron Gap - Ultrafine Mold Fragments, Blood–Brain Barrier Dynamics, and Post-Remediation Neuroinflammatory Risk



Clinical and Building Science Observations-White Paper

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Executive Summary

Post-remediation environments frequently meet visual, moisture, and conventional spore-based clearance standards, yet a subset of occupants continue to experience persistent neurological, inflammatory, and endocrine symptoms. Increasing evidence from aerosol science and environmental toxicology indicates that a significant portion of biologically relevant exposure resides within the ultrafine particulate fraction between **0.12 and 0.3 microns**.

This size range is dominated not by intact spores, but by fragmented fungal material and dust-bound microbial metabolites, including mycotoxins. These particles are exponentially more numerous than larger spores, demonstrate prolonged airborne persistence, penetrate deeply into the respiratory tract, and in experimental models are capable of accessing central nervous system structures via both olfactory and hematogenous pathways.

Importantly, these mechanisms may occur despite negative urine mycotoxin testing, as environmental burden and systemic excretion are governed by different biological variables.

The Exponential Burden of the 0.12–0.3 Micron Fraction

Aerosol physics provides the foundation for understanding this issue. Hinds (1999) established that particle number increases exponentially as particle diameter decreases. In typical indoor air, approximate particle concentrations may follow this order of magnitude:

- ≥5 μm: ~10^3 particles/m^3
- ≥1 μm: ~10^4 particles/m^3
- ≥0.5 μm: ~10^5 particles/m^3
- ≥0.3 μm: ~10^6 particles/m^3
- ≥0.12 μm: 10^7–10^8 particles/m^3

This distribution is not theoretical; it reflects fundamental aerosol dynamics. The practical implication is straightforward: lowering capture thresholds from 0.3 μm to 0.12 μm moves into a particle population that may be **10–100 times more numerous**.

Górny et al. (2002) demonstrated that "Fungal fragments were present in concentrations exceeding those of intact spores and were predominantly sub-micrometer in size.". Cho et al. (2006) confirmed that "Respiratory deposition of fungal fragments is greater than that of intact spores due to their smaller aerodynamic diameter."

Thus, in post-remediation environments where spores are reduced, the dominant inhalable fungal material may consist of fragments in the ultrafine range.

Mycotoxins: Particle-Bound and Independent of Viability

Mycotoxins are low-volatility secondary metabolites that bind to particulate matter rather than existing as freely diffusing gases in typical indoor conditions. Brasel et al. (2005) detected airborne mycotoxins associated with particulate fractions independent of fungal viability. This finding carries two important consequences:

First, eliminating active mold growth does not eliminate toxin-bearing particles.
Second, toxin presence is governed by particle persistence and redistribution.

From a toxicokinetic perspective, inhaled mycotoxins may deposit locally in the respiratory epithelium or nasal cavity without necessarily producing measurable systemic excretion. Urine mycotoxin testing reflects recent absorption, metabolism, and elimination, which vary significantly among individuals due to genetic polymorphisms, liver enzyme activity, renal clearance, timing of testing, and exposure intermittency.

Therefore, absence of detectable urinary metabolites does not exclude inhalation exposure or local inflammatory impact.

Direct Central Nervous System Access: Established Pathways

Olfactory Nerve Translocation

Ultrafine particles in the 0.1–0.3 micron range deposit efficiently in the olfactory epithelium. The olfactory neurons extend axons through the cribriform plate directly into the olfactory bulb.

Oberdörster et al. (2005) demonstrated in experimental models that "Ultrafine particles can translocate to the brain via the olfactory nerve.". Environmental Health Perspectives described this pathway as a direct route by which ultrafine particles may bypass the classical blood–brain barrier (BBB).

While much of this research has involved combustion nanoparticles, the governing variable is particle size and surface chemistry, not source identity.

Blood–Brain Barrier Modulation and Hematogenous Access

Ultrafine particles deposited in the alveoli initiate local inflammatory signaling. Cytokines released in response to particulate exposure can influence BBB integrity. The BBB is regulated by endothelial tight junctions responsive to oxidative stress and inflammatory mediators.

Block and Calderón-Garcidueñas (2009) reviewed evidence linking ultrafine particulate exposure to neuroinflammation and microglial activation. Even in the absence of substantial particle translocation, systemic inflammatory signaling may alter BBB permeability. In addition, "Air pollution particles can initiate neuroinflammation and contribute to neurodegenerative processes."

This dynamic allows circulating inflammatory mediators — and potentially particle-associated compounds to influence central nervous system function.

Hypothalamic–Pituitary Axis Considerations

The pituitary gland and certain circumventricular organs lie outside the classical BBB and possess fenestrated capillary structures. These regions are anatomically more permissive to circulating molecules.

Nanotoxicology literature suggests that ultrafine particles may accumulate preferentially in regions with modified barrier characteristics. Although direct human data specific to mold fragments are limited, the anatomical plausibility for hypothalamic–pituitary interaction exists.

Clinically, dysregulation of the hypothalamic–pituitary axis may present as:

- Fatigue
- Sleep disruption
- Thermoregulatory instability
- Mood changes

- Endocrine irregularities

These symptoms are frequently reported in environmentally sensitive individuals, including those with negative urine mycotoxin testing.

The absence of urinary metabolites does not exclude localized neuroinflammatory signaling at the level of the olfactory bulb, hypothalamus, or pituitary.

Deep Lung Deposition and Systemic Signaling

Particles under one micron penetrate deeply into the alveolar region. Cho et al. (2006) demonstrated efficient alveolar deposition of submicron fungal fragments.

Ultrafine particles possess a high surface area-to-mass ratio, increasing oxidative potential and inflammatory signaling. Even when systemic particle migration is limited, pulmonary cytokine release may propagate systemic effects, including modulation of BBB permeability and neuroinflammatory cascades.

This represents an indirect but biologically plausible pathway linking inhaled ultrafine mold fragments to neurological symptom clusters.

Expanded Discussion: Why Propylene Glycol Fog + ULPA Alters Exposure Dynamics

Traditional HEPA-based cleaning is highly effective at removing spores and coarse particulate matter. However, ultrafine fragments behave differently from larger particles. They adhere electrostatically to surfaces, remain suspended for prolonged periods, and re-aerosolize with minimal disturbance.

Propylene glycol (PG) fogging operates not as a sterilant but as a particle-physics intervention. When properly generated, PG forms a dense aerosol of micron-scale droplets, typically in the 1–5 μm range. Ultrafine particles moving randomly through air due to Brownian motion collide with these droplets. Upon contact, van der Waals forces and hygroscopic adhesion promote binding. Multiple ultrafine fragments may attach to a single droplet, creating composite particles with larger effective aerodynamic diameter.

This process, agglomeration, reduces the number of free ultrafine particles and increases their settling velocity dramatically. Particles that previously behaved like smoke begin to behave like dust. The physics is critical. Fogging does not destroy particles; it changes their behavior to make mechanical removal feasible.

Subsequent ULPA vacuuming provides enhanced capture efficiency in the transitional submicron range. Under EN 1822 standards, ULPA filtration achieves efficiencies typically rated at 99.9995% near 0.12 μm. In high-load fragment environments where concentrations may reach tens of millions of particles per cubic meter, incremental improvements in capture efficiency translate into meaningful reductions in residual burden.

Agglomeration makes removal possible. ULPA maximizes removal completeness. Together, they address the dominant particle fraction that persists after conventional remediation.

Limitations of ERMI and Mold Plate Testing

ERMI testing quantifies DNA from selected mold species in dust samples but does not measure particle size distribution, ultrafine fragment burden, or toxin carriage. Mold plate testing captures viable spores capable of growth under laboratory conditions but does not detect non-viable fragments or dust-bound mycotoxins. Both methods provide useful information yet underestimate exposure dynamics governed by submicron particle physics.

Limitations and Areas for Further Study

While mechanistic evidence supports ultrafine particle translocation and neuroinflammatory signaling, direct human data specific to mold fragment ultrafines remain limited. Much of the neurological pathway research derives from combustion particle models. Quantitative thresholds for clinical effect in mold-fragment–specific environments require further investigation. Standardized field methods for measuring submicron fungal fragment burden are also underdeveloped relative to spore-based methodologies.

Addressing Skepticism

It is appropriate to anticipate skepticism from industrial hygienists, building scientists, and physicians. Several common concerns arise when discussing ultrafine mold fragments and neurological implications.

> *"Most of the brain-access literature involves combustion particles, not mold."*

This is accurate. Much of the direct olfactory translocation research has involved engineered nanoparticles or combustion-derived ultrafines. However, the biological mechanism described by Oberdörster et al. is governed by particle size and surface properties, not exclusively by source category. The argument is not that mold fragments behave identically to diesel particles, but that particles within a similar aerodynamic size range may utilize similar anatomical pathways.

> "Urine mycotoxin tests are negative, so exposure must be low."

Urine testing reflects systemic absorption and excretion over a limited time window. It does not measure local deposition, localized inflammatory signaling, or tissue-level interaction. Environmental dust burden and urinary excretion are not linearly correlated because absorption, metabolism, sequestration, and elimination vary substantially among individuals. Negative urine testing therefore does not exclude inhalation exposure or neuroinflammatory signaling.

"HEPA filters capture particles smaller than 0.3 microns due to diffusion."

This is correct. HEPA efficiency improves below the most penetrating particle size (MPPS) due to diffusion mechanisms. However, two clarifications are important. First, the exponential

increase in particle number below 0.3 microns means that residual burden may remain significant even after high-percentage capture. Second, capture efficiency assumes effective entrainment. Submicron particles adhering electrostatically to surfaces may not be fully entrained without modification of their physical state. This is the rationale for agglomeration prior to removal.

> *"There is no direct human evidence linking mold fragments to pituitary dysfunction."*

Direct, controlled human data specific to mold fragment deposition in pituitary tissue are indeed limited. The argument presented is one of anatomical plausibility and mechanistic extrapolation, supported by known vulnerability of circumventricular regions and BBB modulation under inflammatory conditions. The paper does not claim definitive causation; it presents a biologically coherent hypothesis requiring further study.

"Is this overstating risk?"

The intent is not to overstate risk but to contextualize persistent symptoms in some individuals whose homes have passed traditional metrics. The literature clearly establishes:

- Ultrafine fragments exist in high concentrations
- They deposit efficiently in lung tissue
- They can translocate via olfactory pathways
- They can induce neuroinflammatory signaling

Whether specific individuals experience clinically meaningful effects depends on dose, duration, susceptibility, and coexisting conditions. Recognizing this variability strengthens, rather than weakens, the argument.

Conclusion

The 0.12–0.3 micron fraction represents a biologically consequential domain in post-remediation environments. These particles are exponentially more numerous than spores, respirable, capable of deep lung deposition, and mechanistically capable of interacting with central nervous system structures through olfactory and inflammatory pathways. Anatomical considerations suggest potential vulnerability of hypothalamic–pituitary structures.

These processes may occur despite negative urine mycotoxin testing, reflecting the complexity of environmental toxicokinetics and localized inflammatory signaling.

Addressing this particle fraction reframes post-remediation cleanup as a problem of particle physics and biological interface rather than microbial viability alone.

It is essential to state clearly that this white paper does not assert that all mold exposure results in brain penetration or endocrine dysfunction. Rather, it presents a mechanistic framework explaining how ultrafine particle dynamics may contribute to persistent symptoms in susceptible individuals even when traditional remediation endpoints are achieved.

The discussion focuses on exposure physics and biological plausibility, not diagnostic claims.

Key References

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