

INDOOR PARTICLE DYNAMICS IN RESIDENTIAL BUILDINGS: FROM A FEW NANOMETERS TO TENS OF MICROMETERS

ABSTRACT

Indoor environments are filled with diverse and dynamic sources of airborne and surface-bound particles, ranging in size from nanometers to tens of micrometers. This broad size range leads to a complex interplay of physical processes that govern how particles transport, transform, and ultimately affect human inhalation exposure. Unlike the outdoors, indoor spaces are influenced by constant human activity and building characteristics, which introduce often intense particle emissions. This dissertation explores the behavior of indoor particles across a range of indoor sources and sizes, focusing on how they are generated, how they evolve, and what are their exposure implications.

One major contributor to indoor atmospheric particles is indoor combustion. Field measurements in a residential test house revealed that propane gas stoves and scented candles emit significant quantities of nanocluster aerosol (NCA; 1–3 nm nanoparticles). These particles often reach concentrations and respiratory doses higher than those from urban outdoor traffic, with children receiving disproportionately higher respiratory doses than adults during gas cooking. Interestingly, non-combustion-based induction cooking also enriches indoor atmosphere with nanoparticles.

Beyond combustion, many everyday activities, such as cleaning, aromatherapy, and personal care, release high concentrations of reactive terpenes into indoor air. These terpenes react with ozone indoors, triggering intense new particle formation (NPF) events. The resulting indoor atmospheric nanoparticles form and grow at rates that, in some cases, exceed those observed during emissions from combustion-related nanoparticle sources. To capture and understand these complex transformations, a novel indoor nanoparticle material balance model was developed, incorporating key physical processes like nucleation, condensation, coagulation, deposition, and ventilation.

Larger particles are also present in indoor air, with humans being a significant source of these particles. Field measurements revealed a strong positive correlation between super-micron fluorescent aerosol particles (FAPs) and both human presence and ventilation patterns. Altogether, the findings presented in this dissertation highlight the presence of ubiquitous indoor atmospheric particle sources, their transient dynamics, and underscore the importance of routinely monitoring indoor atmospheric particles.