AIRBORNE PARTICLE SIZES AND SOURCES FOUND IN INDOOR AIR

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As concern about indoor air quality (IAQ) has grown, understanding indoor aerosols has become increasingly important so that control techniques may be implemented to reduce damaging health effects and soiling problems. Particle diameters must be known to predict dose or soiling and to determine efficient mitigation techniques. This paper summarizes the results of a literature search into the sources, sizes, and concentrations of indoor particulates, including the various types: plant, animal, mineral, combustion, home/personal care, and radioactive aerosols. This information, presented in a summary figure, has been gathered for use in designing test methodologies for air cleaners and other mitigation approaches and to aid in the selection of air cleaners.

INTRODUCTION

Knowledge of sources, sizes, concentrations, phases, and composition of indoor aerosol is important because of potential health effects and problems related to deposition on surfaces as summarized below.

Health Implications

The single most important feature in lung deposition is particle size. Particles larger than 30 μm in aerodynamic diameter are unlikely to enter the nose. The rapid changes of airflow direction in the nose and pharyngeal region favor deposition of larger particles, usually 5 to 10 μm in diameter. In the tracheal bronchiolar region, these changes decrease so that the 1 to 5 μm range is favored. As the velocity decreases, sedimentation increases, resulting in fewer particles reaching the alveoli. Gravity is less important for smaller particles; thus, particles less than 1 μm are deposited on alveolar walls mostly by diffusion.

The interaction between particles and cells depends largely on deposition site. However, dose also depends on solubility of the particles, and other aspects as well (1-4).

Soiling

Problems caused by indoor aerosols include deposition on surfaces, which results in dirty floors and windows, failure of precision machinery, soiled art, etc. The diameters determine the particles' paths, whether they deposit on a surface, remain airborne, or are removed by cleaning devices (5, 6).

Aerosol Formation and Removal

Aerosols are formed by many mechanisms. Condensation produces small liquid particles. Combustion results in small liquid and solid and large solid particles. Nuclear degradation results in ultra-small particles. Resuspension results in large solid particles reentering the air. Spraying yields medium liquid or small solid particles.

Adhesion forces arise from particle and surface properties, interface geometry, and condensed gas constituents. When small aerosol particles deposit on a solid surface, they usually adhere on contact due to these forces. Electrostatic charge consists of an excess or deficiency of electrons or ions. Charged particles collect on oppositely charged surfaces.

Particle sedimentation occurs on horizontal surfaces. The settling velocity of a small sphere is proportional to the diameter squared. Impaction occurs when a particle collides with an obstacle in the flow path. Since smaller particles tend to flow around an obstacle, impaction shifts the size distribution toward the smaller particles.

Diffusion, the result of particulate bombardment by gas molecules or Brownian motion, is an important mechanism for particles less than 1 μm in diameter. Diffusion can result in surface deposition. Particles may collide and coagulate to form larger particles. This is the primary process for removing small particles from the air. In addition, particles smaller than a certain critical diameter will evaporate.

Understanding these forces will allow prediction of which particles will be inhaled, resulting in potential health problems and which will deposit, resulting in soiling or damage to surfaces. Knowledge of particle size will enable selection of control measures (4, 7, 8).

PARTICLES IN INDOOR AIR

An important approach to assessing indoor particulate contamination is to identify sources, then to determine the sizes, phase(s), and typical concentrations of the particles these sources produce. Since indoor activity may entrain (for short periods) particles larger than those normally considered aerosols, these particles have been included. Figure 1 shows the reported size ranges for many indoor particles, grouped by six source types: plant, animal, mineral, combustion, home/personal care, and radioactive aerosols.

Plant Aerosols

Plant particulates include pollens, spores, molds, and miscellaneous by-products. Most are of outdoor origin and enter through windows, doors, and heating, ventilation, and air-conditioning (HVAC) systems.

Pollen and spores are seasonal and are often too large to remain in the air for prolonged periods. However, sweeping or dusting may re-entrain them causing an aerosol problem. These particles present a special hazard as allergens. (For many people, allergic reactions outweigh potential lung deposition as a health concern.) Molds are present all year with the greatest concentrations during wet periods. One source is ultrasonic humidifiers where molds may grow in stagnant water and then be aerosolized. Molds are potential allergens, can be unsightly, will stain, and may ruin furniture. Mold may grow on filters, causing the HVAC system to exacerbate the problem (9).

Miscellaneous plant particulates include finely ground grains, coffee and cornstarch. These particulates are introduced by the occupants--opening such containers results in some air contamination. However, much settles out rapidly and is usually confined to a small portion of the building. Source control or venting is simpler than for pollens and molds (10).

Animal Aerosols

These particles may be small and remain airborne for long periods, or large and only remain in the air for short periods. This type includes bacteria, viruses, hair, and insect parts.

Bacteria may come from outdoors by air, in water, on shoes, with equipment, etc. People transport bacteria on their clothing and in their bodies. Bacteria become airborne through many mechanisms. Since they are small, slight breezes may pick them up. House cleaning may spread them and humidifiers spray them. Bacteria that grow in duct work or on filters are spread through the HVAC system. People aspirate them as droplet nuclei. Disease bacteria present a special problem since they may cause illness. Droplet nuclei are in the size range shown to have increased infectivity when aspirated. Bacterial infection may spread through an entire building through the very equipment intended to purify the air. However, in many cases bacteria can be controlled using standard disinfectants (11).

Viruses are much smaller than bacteria, stay airborne longer, and are likely to pass through filters (3).

Hairs are often too big to remain aerosols but will be airborne occasionally. In addition to inhalation problems, hairs are important from the allergy and soiling perspectives. However, hairs are relatively easy to collect and a filter will trap them. Epithelial cells flake off as a normal part of growth; dandruff is simply epithelial cells clumped together.

Insect parts and by-products can become aerosol particles. One example is the house dust mite. House dust mite feces are a major source of allergic reactions to dust. The feces disintegrate to form respirable particles. Commonly recommended methods to reduce exposure to this allergen involve source control instead of air cleaners (9, 12).

Mineral Aerosols

Mineral aerosols may be carcinogenic or mutagenic and present problems by contaminating industrial environments and soiling furniture, etc. These particles include asbestos, carbons, clays, elemental particles, and man-made fibers (13).

Asbestos is a carcinogenic fiber, formerly used in insulation. Contamination occurs when insulation degrades releasing fibers and when asbestos is removed. Talc, another mineral particle, is the major component of body powders, which are introduced by the occupants at controllable intervals. While many of these particles settle out of the air rapidly, others are inhaled since use occurs close to the breathing zone.

Man-made mineral fibers (MMMF) are used extensively in building materials, manufactured products, and textiles. They may be manufactured from ceramics, glass, rock, etc. They enter with the outdoor air or can be generated in ventilation systems or when ceiling boards are damaged. MMMF handlers have reported skin irritation, respiratory tract irritation, and eye problems.

Combustion Aerosols

Sources of this particle type include tobacco products, cooking, heating appliances, and industrial plants. Most of these particles are in the respirable range and need to be considered in IAQ control system design. These sources are frequently vented individually; e.g., chimneys are built for fireplaces. These particles are a major source both of outdoor and indoor particles (14).

Tobacco smoke, the primary source of aerosol in smoking environments, contains particles and organic compounds. Liquid particles and gases that condense on filters may outgas later. The majority of these particles is smaller than 1 μm. Tobacco smoke creates allergy, odor, and soiling problems. Burning wood, other heating fuels, and cooking sources also produce particles in the respirable range. These sources are difficult to eliminate as they are integral to comfort and lifestyle (15).

Industrial sources may pollute the ambient air to the extent that they contribute noticeably to indoor counts. In these cases tight controls on inlet air are important (6).

Home/Personal Care Aerosols

These products, including antiperspirants, dusting aids, and hair sprays, are mostly sprays used in the home which produce low total mass but in a short time so that the initial concentration is high. Since product use is mostly in the breathing zone, the dose may be quite high. One problem peculiar to this type of aerosol is that these products are often designed to stick to surfaces often resulting in cleaning problems (7).

Radioactive Aerosols

Radioactive aerosols are introduced when radon enters through cracks, in the water, or from exposed rock or sumps. Radon decays to form progeny through nuclear degradation. These particles are ultra-small and may attach to larger particles.

SUMMARY

Understanding indoor aerosols is important so that control techniques may be implemented to reduce damaging health affects and soiling problems. A brief look at the mechanics of deposition in the lungs and on surfaces shows that particle diameters must be known to predict dose or soiling and to determine efficient mitigation devices.

There are several types of indoor particulates: plant, animal, mineral, combustion, home/personal care and radioactive. They may be produced indoors or outdoors, entering through building openings. The sources may be short-term, seasonal, or continuous. The particles may be toxic, allergenic, or neutral. All of these particles contribute to the indoor aerosol problem.

REFERENCES

1. Task Group on Lung Dynamics (1966) Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract, Health Phys 12:173-207.

2. Turiel I (1985) Indoor Air Quality and Human Health, Stanford University Press, Stanford, California.

3. Knight V (1980) Viruses as Agents of Airborne Contagion, Annals New York Academy of Sciences. 147-157.

4. Hinds WC (1982) Aerosol Technology, John Wiley and Sons.

5. Baer NS and Banks PN (1985) Indoor Air Pollution: Effects on Cultural and Historic Materials, The International Journal of Museum Management and Curatorship. 4:9-20.

6. McElroy MW, Carr RC, Ensor DS, and Markowski GR (1982) Size Distribution of Fine Particles From Coal Combustion, Science, 215:4528.

7. Mokler BV, Wong BA, and Snow MJ (1979) Respirable Particulates Generated by Pressurized Consumer Products. II. Influence of Experimental Conditions, AIHA Journal. 40:339-347.

8. Fisk WJ, Spencer RK, Grimsrud DT, Offerman FJ, Pedersen B, and Sextro R (1987) Indoor Air Quality Control Techniques, Noyes Data Corporation, Park Ridge, NJ.

9. Ishii,A, Takaoka M, Ichinoe M, Kabasawa Y and Ouchi T (1979) Mite Fauna and Fungal Flora in House Dust from Homes of Asthmatic Children, Allergy. 34:379-387.

10. McCrone WC and Delly JG (1973) The Particle Atlas Vol. II, Edition II, Ann Arbor Science Publishers, Ann Arbor, MI.

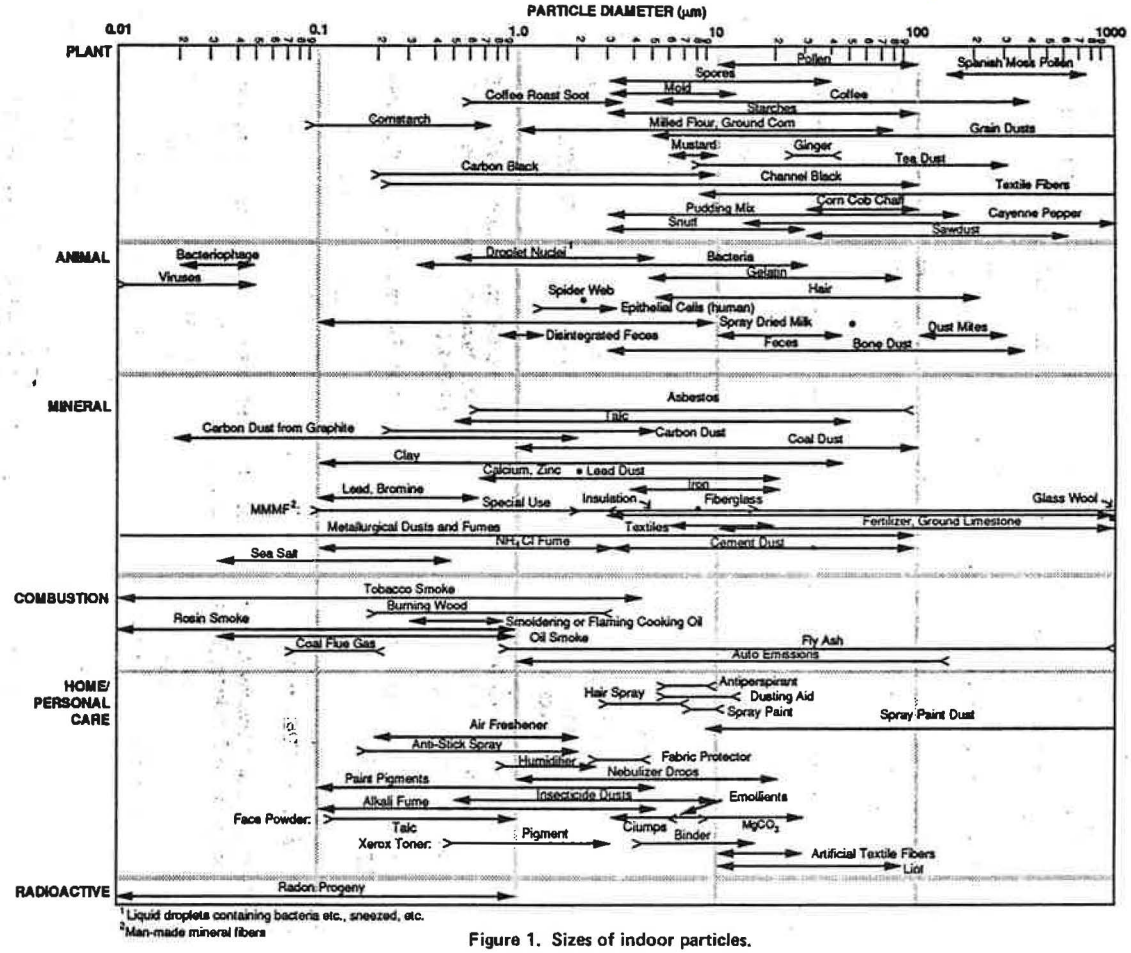
11. Arnow PM, Chou T, Weil D, Shapiro EN, and Kretzchmar C (1982) Nosocomial Legionnaires' Disease Caused by Aerosolized Tap Water from Respiratory Devices, The Journal of Infectious Diseases. 146:460-467.

12. Nelson HS, Hirsch R, Ohman JL, Platts-Mills TAE, Reed CE and Solomon WR (1988) Recommendations for the Use of Residential Air-cleaning Devices in the Treatment of Allergic Respiratory Diseases, Journal Allergy Clin Immunol. 82:661-669.

13. Schneider T (1986) Manmade Mineral Fibers and Other Fibers in the Air and In Settled Dust, Env Int. 12:61-65.

14. Tu KW and Hinchliffe LE (1983) A Study of Particulate Emissions from Portable Space Heaters, AIHA Journal. 44:857-862.

15. Repace JL and Lowrey AH (1985) A Quantitative Estimate of Nonsmokers' Lung Cancer Risk from Passive Smoking, Env Int. 11:3-22.



[1] Liquid droplets containing bacteria etc., sneezed, etc.
[2] Man-made mineral fibers

Figure 1. Sizes of indoor particles.