Brief Introduction to Aerosols (Airborne Particulates) and Their Importance in Biosafety

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Nomenclature Deposition in the Lungs Breathing Zone Biosafety Practices Filtration Biological Safety Cabinets and Respirators BSLs, Risk Assessments and use of BSCs

In the discipline of Biological Safety, protection against infectious aerosols is a major theme, only slightly overshadowed by hand washing. In the vernacular of people who design filters and others, nebulized liquids, infectious droplets from coughs, sneezes, and sonicators, mists from sprayers, wafted powders from hazardous chemicals, spray paints, fumes from soldering and welding, sloughed-off asbestos, and all manner of other airborne wet or dry particles are aerosols (see first illustration below). Vapors from evaporated solvents and gases are airborne as individual smaller molecules and are not considered to be particles or aerosols.

One difference between aerosols and vapors/gases is the mechanism of an inhalation exposure. Compared to aerosols, vapors and gases are negligibly small and their entrance into the blood stream through the lungs is by the mechanism of diffusion. Aerosols are much larger and vary widely in size. Their arrival into the lungs is dependent on size. Speaking generally, the only particles that are deposited in the alveoli are between 1 and 5 micrometers in diameter. Smaller particles don't actually deposit by impaction, if they are present in the air in the alveolus, they diffuse from the air into the cells of the alveolus, but may also be flushed out when the air changes (not necessarily each breath). Particles that are larger than 5 micrometers are more likely to be deposited in the ever-narrowing passages that lead from the nostrils or mouth to the alveoli. In many cases, upper respiratory deposition of aerosols results in an ingestion or mucous membrane exposure to the aerosol.

In still air, all aerosols fall at some speed called the sedimentation rate. This rate varies from seconds to hours per meter, according to the mass, size and shape (in some cases modified by evaporation rate) of the particles. Air is a mixture of gases and while aerosols settle, vapors and gases from a concentrated source may settle or float in still air, molecular weight being the main determinant. In laboratories, air is made to circulate for this very reason, it is removed and replaced by the general ventilation for the purpose of removing contaminating aerosols, gases and vapors by mixing. So in the laboratory, there is already considered to be an exchange of contaminated by less contaminated air in each person's breathing zone that gives a certain amount of protection against inhalation exposures. The trouble is, that the exchange comes about as the result of the mixing of cleaner air with contaminated air, and/or as the result of air currents and turbulence, which, it is hoped, will bring mostly cleaner air into the breathing zone. In the midst of this dynamic process, a concentrated source of contamination may generate a cloud of aerosols, vapors or gases that can overcome the ventilation process and exist in a person's breathing zone long enough for an inhalation exposure to occur. Depending on the contaminant and its concentration. even a momentary exposure may be significant (e.g., when, at the moment of the inhalation, the proper multiplicity of infection of an infectious microorganism is present in the breathing zone. This is believed to be the cause of a significant proportion of laboratory-acquired infections.)

To overcome this aerosol problem while culturing infectious materials, biological safety cabinets (BSCs, an engineering control) and respirators were developed. Ironically, despite these elaborate measures it is one's skill at standard microbiological procedure and precautionary practices (not producing aerosols, washing hands, personal protective equipment (PPE, gloves, lab coat, eye/face protection and use of the BSC when aerosols are unavoidable) that seems do the most to prevent laboratory-acquired infections.

Both BSCs and respirators depend on high efficiency particulate air (HEPA) filters to protect researchers against infectious particles. Most BSCs (Class II, type A/B3 [now designated A1and A2]) at the UCHC take air from the lab, filter it and return it to the lab. Because they do not capture gasses and vapors, they do not protect against hazardous chemical vapor exposures. (There is concern that, if enough flammable chemical is present, this kind of BSC can concentrate the vapor to the point where the sparks in the motor can ignite the vapor.) Hazardous powdered chemicals (that would not sublimate) might be used in such a BSC, but the decontamination process used to remove the filters isn't aimed at deactivating such chemicals so if this is unavoidable, Research Safety should be notified and a sign should be placed on the BSC to alert maintenance personnel, as with chemical fume hoods.) HEPA filters are least efficient (99.97%) for particles that are 0.3 micrometers in diameter using dioctylphthalate. They are more efficient for larger and smaller sizes. They become more efficient at capturing particles as they clog up, and less efficient at passing air. Usually, once the pressure differential across them is 125 Pascals, they are changed. Respirators fitted with HEPA filters may be used to protect researchers against infectious particles, but only when a BSC cannot be used and when a respirator program is in effect with that researcher. The respirator program entails annual fit tests, training, respirator maintenance records, medical examinations and clearance, and no facial hair. Respirators may be fitted with other filters or multiple filters to protect against other inhalation exposures such as organic vapors. The same restrictions apply to all respirator use. Respirators should be needed only rarely for laboratory or animal laboratory use, since most protection should come from BSCs and chemical fume hoods.

At Biosafety Level 2 (BSL-2) a risk assessment of manipulations with infectious materials needs to take place to determine what manipulations potentially create infectious aerosols and must therefore take place inside the BSC. (This is not the case for BSL-3 where all manipulations take place inside the BSC.) All researchers are invited to get assistance from Research Safety in performing risk assessments for work in their labs. These risk assessments should become part of the individual lab's safety documentation. Typical sources of infectious aerosols include: centrifugation, pipetting when the pipette is emptied (especially blown out), sonicating, blending, grinding, shaking, vortexing, flaming inoculation loops (see second illustration below), opening snap-cap tubes when the top is wet, opening tubes with pressure inside, falling drops and spills, inside aspirator vacuum bottles, etc. It is important to remember that aerosols persist, so that if one is created inside a container, it may be released when the container is opened, unless an appropriate time is allowed for settling.

(Please see the illustrations below)



The sizes of various airborne contaminants. (Courtesy MSA.)

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Inoculation Loop loaded with fluorescein being flamed.



3 fluorescein spots show up under UV light, next to the burner base. Supplied on biosafty listserv by Richard Fink.

Flaming can create aerosols if one sticks the contaminated end of the loop/needle directly into the flame. One gets instantaneous boiling that ejects viable material. If one starts at the base and works one way to the tip, the tip will be sterilized without the creation of viable aerosols. Attached are two slides demonstrating aerosolization using fluorescein dye. Photographic illustrations courtesy of Richie Fink and his Biosafty listserve.