WHITE PAPER:

Aerosol Hazard Management 101

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Introduction

Emergency responders have many decisions to make when considering personal protective equipment (PPE) selection, detection, identification, and hazard mitigation. One major consideration is the phase of matter that will be encountered on scene. Chemical hazards come in all phases: gases, liquids, solids, and vapors (the gaseous component in equilibrium with volatile liquids and solids). In addition to the major phases, there is a critical quasi-phase that must also be considered: aerosols.

Aerosols are discrete solid particles or liquid droplets suspended in a fluid medium, typically air[1]. There are common examples of aerosols all around us:

- Dust (dirt particles)
- Fog (water droplets)
- Smoke (combustion product particles)

While many aerosols are indeed common, aerosolized chemicals pose a unique challenge for responders because they keep their condensed phase properties, but behave like gases, with fluid dynamics. This often poses a problem for traditional detection technologies used by responders that require an unknown sample to be in gas, solid, or liquid form to be analyzed.

This white paper defines aerosols and their properties, explains the hazard posed by them, and provides a strategy for emergency responders to address aerosols in the field.

For the purposes of this discussion, the term "particle" will be used to describe both solid and liquid aerosols.

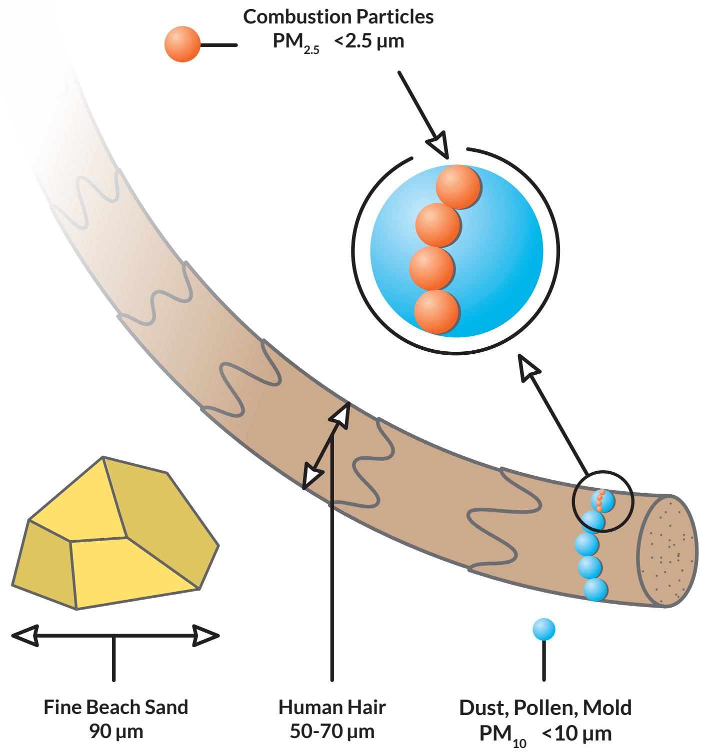
Defining aerosols and their properties

To the eye, aerosols may look much like a gas cloud or plume, where particles are freely moving through the air. But the critical, defining trait of an aerosol is that the plume actually contains many fine solid or liquid particles. As a result, it is important to consider these unique properties, because how we respond to these threats depend on it.

Key Aerosol Properties

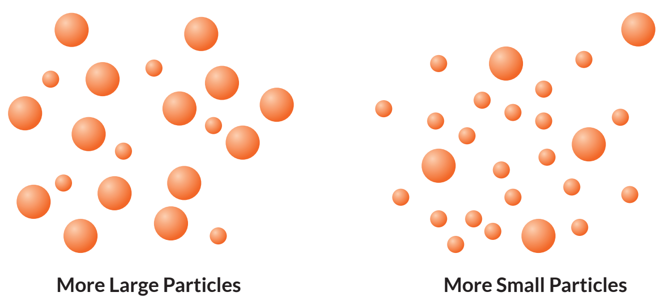
Particle size: The first property is the size of the solid or liquid particles that are suspended. The particle size is the diameter of a single particle expressed in micrometers, or "microns" (10^{-6} m). Small particles are easier to inhale and tend to resist settling for longer.

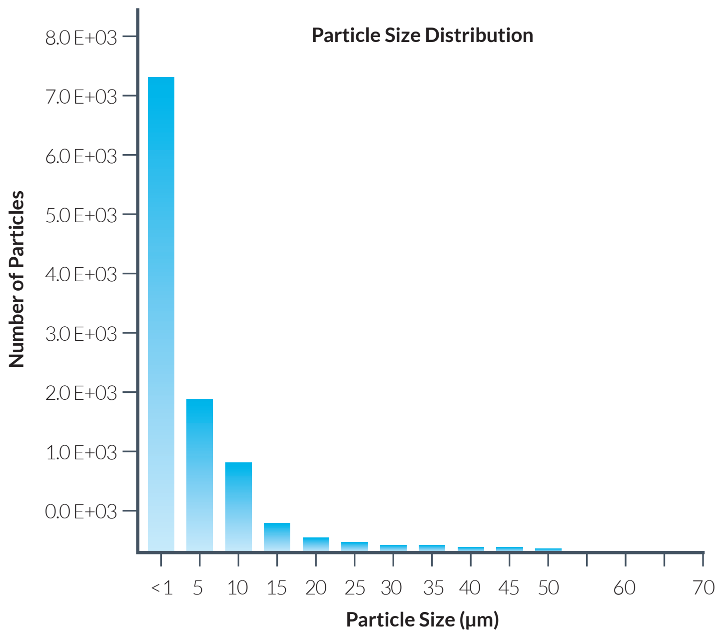
PARTICLE SIZE



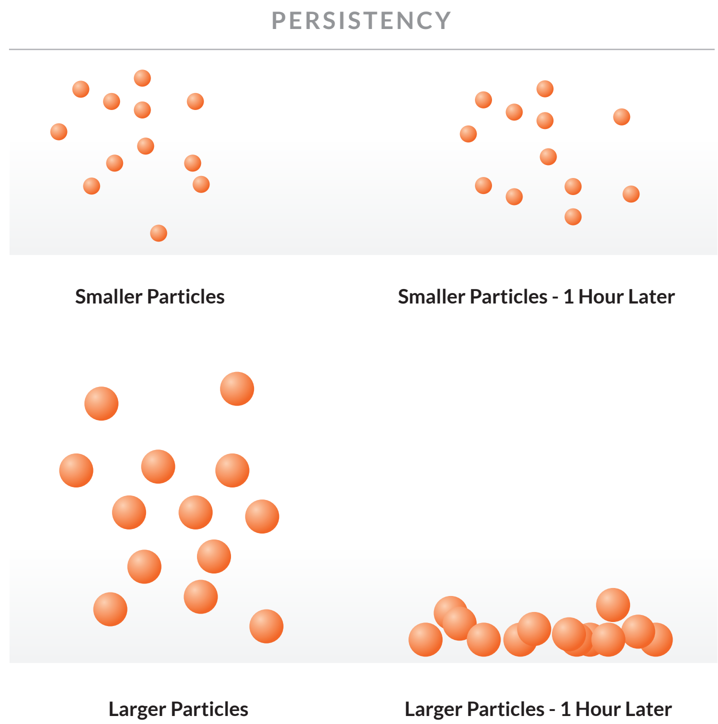
Particle size distribution: The second property is particle size distribution, which is defined as the number of particles within a sample which have a given size or mass. Particle size distribution is important because particles within an aerosol plume are not uniform. Varying sizes will affect how long the aerosol is suspended and how easily they can be inhaled.

PARTICLE SIZE DISTRIBUTION

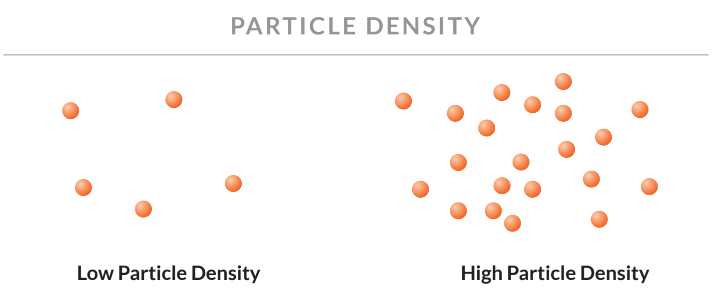




Example showing potential particle size distributions of solid particles that could be aerosolized



Particle density: Represents the total number of particles within a given volume of air. Anyone who has driven on a foggy night knows that the water particles in the atmosphere are large enough (particle size) to scatter white light from headlamps, and there are enough of them (particle density) to obscure visibility.



Persistency: The final aerosol parameter which is less easily quantified is persistency, or the ability of the particles to remain suspended in the fluid medium. As mentioned earlier, smaller particles will tend to remain suspended longer than larger ones. However, electrostatic properties can also influence this, as charged particles will tend to repel each other and stay in the air.

When a responder encounters an aerosol, these properties govern how the aerosol will behave and are critical to determining proper isolation distances and managing decontamination as the aerosol settles. Also, depending on the properties, the aerosol may be more or less dangerous for responders and bystanders and could further guide incident response.

Understanding the hazard posed by aerosols

At its most basic level, particle size is critical in terms of how easily an aerosol can be breathed in and captured in the lungs. The U.S. Environmental Protection Agency (EPA) defines two different particle sizes in this regard[2]. PM_{10} represents inhalable particles that are 10 microns or smaller, whereas $PM_{2.5}$ represents fine inhalable particles that are 2.5 microns or smaller. Of these, $PM_{2.5}$ are the most dangerous as they can reside in the lungs and get into the bloodstream. This is why filter masks such as N95 and P100 are rated for their ability to trap 2.5 micron particles.

When it comes to inhalation hazards, solid and liquid chemicals generally present minimal hazards compared to gases and vapors. Condensed phase products are easily contained, and the isolation distance for a small pile of powder or a puddle of liquid can be maintained at a few meters.

However, if that toxic material is aerosolized, it becomes much more difficult to manage. The aerosolization can occur unintentionally by disturbing the product. That is why care must be taken on-scene when dealing with highly toxic powders like fentanyl and related synthetic opioids. A greater concern is the intentional aerosolization of materials in the case of a chemical attack.

As an example, a kilogram of fentanyl, which represents millions of lethal doses[3], could be packaged with an incendiary device or a mechanical dispersion system (such as a crop sprayer) to disseminate the product over a wide area of potential victims. Some fraction of the dispersed fentanyl particles will have particle sizes that make them persist in the air, making inhalation and/or transdermal exposure the primary concerns. As the particles settle over a wide area, surface contamination (and subsequent re-aerosolization) become secondary concerns.

The MX908® from 908 Devices has been available to responders for years as a handheld mass spectrometry device, bringing the power of the lab into the field.

Furthermore, aerosolized particles can pose an explosion hazard in the presence of oxygen if the particles are combustible, they are present in a sufficient particle density, and there is an ignition source. This is why a primary hazard for relatively benign products such as sawdust and even sucrose (table sugar) in a confined space is "combustible."[4] Whether aerosolization is unintentional or not, detecting particles suspended in the air and on contaminated surfaces is critical for emergency responders. Unfortunately, aerosol detection capability has been a challenge for the existing meters in the first responder's toolkit.

The challenge of detecting and identifying aerosols

When responding to a situation with an unknown material, it's critical to detect and identify that material to remediate the scene. In the past, point-of-need detection and identification of aerosolized chemicals was not possible. Waiting for aerosols to settle and direct swabbing surfaces was an option, but depending on particle size, this could take hours and increases the chance of inhalation.

Many tools that are traditionally found in the responder's toolkit can directly monitor the air or classify a bulk sample of a chemical—not an aerosol. Four-gas meters, photoionization detectors (PIDs), ion mobility spectrometers (IMS), and colorimetric tubes only detect products which are natively in the gas or vapor phase. Chemical papers such as pH, or sophisticated optical meters based on infrared and Raman spectroscopy, require bulk amounts of condensed phase material to analyze. Even gas chromatography-mass spectrometry (GC-MS) systems require a product to either be in the gaseous or condensed phase. None of these technologies have capabilities for aerosolized threats.

The most recent innovation to date for detecting aerosols in the field has been devices that use laser light scattering to count and size aerosol particles. This technology is a step toward understanding the aerosolized hazard, but provides no inherent chemical information about the sample. This ultimately means that the responder is still without answers in an unknown situation.

A solution for detecting and identifying aerosolized threats

The MX908® from 908 Devices has been available to responders for years as a handheld mass spectrometry device, bringing the power of the lab into the field. It has been adopted by responders around the world, including the US and foreign militaries and many other federal, state, and local responders. Using a variety of sampling techniques, including swabbing and air sampling, a responder can use the MX908 to detect and identify many hazardous chemicals, even down to trace samples that the eye simply cannot see.

The MX908 is also a powerful tool when it comes to detecting and identifying aerosolized particles. With the addition of the Aero, the MX908 is able to sample threats in any state, including aerosols. By simply attaching the Aero to the MX908, the user is able to simultaneously detect and identify vapors and aerosols. It is optimized to collect greater than 80% of all particles with diameters greater than 2.5 microns to focus on the hazardous inhalable particles as defined by the EPA[2].

The MX908 with Aero achieves this ability by trapping particles onto a mesh screen, which is periodically flash-heated and desorbed to convert the sample into vapor. The vapors are then read by the MX908, and any threats are immediately reported to the operator. Chemical warfare agents, Fourth Generation Agents (A-series/Novichoks), fentanyls and other Pharmaceutical Based Agents, and a variety of other highly toxic chemical materials are all within the capability of the MX908 Aero.

Ensuring the complete toolkit for aerosol hazard management

To have a strong and swift response to threats and unknown hazards, it is critical to have the right tools to address the problem. In the past, aerosolized chemicals presented a gap simply because technology had not advanced far enough to provide rapid insights for samples with such complex properties. However, that gap has been addressed through the MX908 and Aero module which samples, traps, and identifies aerosolized material. With an understanding of aerosol properties and detection technology to identify the substance at the point of need, a responder can make a confident assessment and plan for the safety of everyone involved.

REFERENCES:

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2. Internet, https://www.epa.gov/pm-pollution/particulate-matter-pm-basics, Accessed 4 March 2021.
3. Internet, https://www.dea.gov/sites/default/files/2020-06/Fentanyl-2020_0.pdf, Accessed 9 March 2021
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The MX908 Aero can detect aerosol particulates dispersed from an explosive device.

The MX908 with the Aero attached.

An operator using the MX908 can conduct post-blast analysis on-site with the Aero.

Learn more about MX908 at **908devices.com/MX908**

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