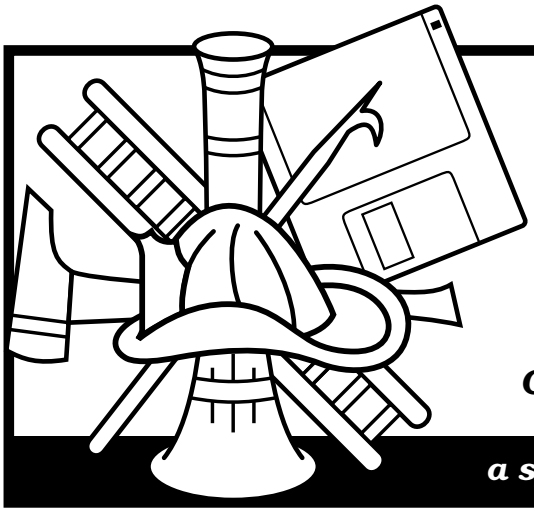


Comparing Three Primary Threats at a Hazmat Incident

Oxygen Deficiency, Toxicity, Flammability

a special publication from Firebelle Productions

Introduction

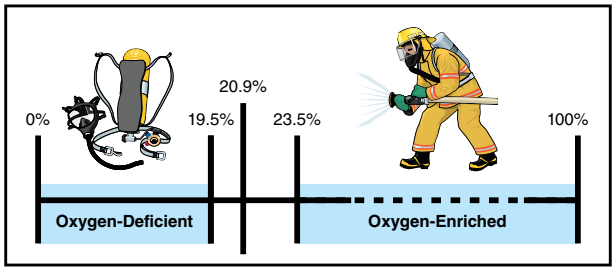
We often evaluate hazmat incidents in terms of three primary threats: oxygen deficiency, toxicity, and flammability. These three threats affect many of the decisions we have to make, for example, what PPE to wear or what protective actions to implement.

This newsletter is designed to help you compare these three threats. However, it is not a substitute for the more thorough risk assessment.

Three primary threats (oxygen deficiency, toxicity, and flammability) affect many of the decisions we have to make as emergency responders.

Evaluating Oxygen-Deficient (and Oxygen-Enriched) Atmospheres

The normal atmosphere contains roughly 78% nitrogen, 20.9% oxygen, and 1.1% argon and other gases. Although 20.9% oxygen is considered normal, we don't hit the "threat zones" until we drop below 19.5% or rise above 23.5%.



If the oxygen level is above 23.5%, the atmosphere is considered potentially explosive. An oxygen-enriched atmosphere will cause any flammable or combustible material to ignite more readily and burn more fiercely. It's unsafe to enter an oxygen-enriched atmosphere.

An oxygen concentration of 19.5% is considered by OSHA and NIOSH to be the minimum safe level. Below that, the atmosphere is oxygen-deficient and responders must wear self-contained breathing apparatus (SCBA) or supplied air respirators (SAR). Air purifying respirators (APR) are not acceptable, even if they are capable of filtering the specific contaminants in the atmosphere, because they don't provide responders with a source of oxygen.

An oxygen concentration of 19.5% is considered to be the minimum safe level.

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Evaluating Oxygen-Deficient Atmospheres

An atmosphere with less than 19.5% oxygen is not an immediate threat to life. There's still a margin of safety. However, oxygen deficiency does affect mental and physical abilities.

Oxygen	Effects of Oxygen Deficiency
20.9%	normal concentration
19.5%	minimum OSHA/NIOSH safe level, but doesn't address possible contaminant concentration
↓	increasing impairment to breathing, coordination, perception, and judgment
6%	difficulty breathing, convulsions, death in minutes

Any displacement in the oxygen concentration is an indication there may be a contaminant present in the atmosphere. Since oxygen comprises roughly one fifth (1/5) of the normal atmosphere, a 1% displacement (from 20.9% to 19.9% oxygen) means there is roughly a 5% concentration of a contaminant gas. In other words, although your oxygen meter shows a 1% displacement, that contaminant gas is really displacing one part oxygen and four parts everything else. Further monitoring is required.

Note: Some atmospheric monitors, such as combustible gas indicators, require at least 16% oxygen to function properly. If the oxygen level is less than 16%, meter readings may not be accurate.

Evaluating Toxicity

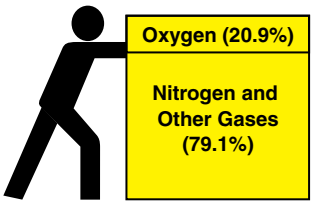
Contaminant concentration is often cited in percent by volume in air (%) or in parts per million (ppm) or parts per billion (ppb). A concentration of 1% is equal to 10,000 parts per million (ppm) or 10,000,000 parts per billion (ppb).

% by Volume	ppm	ppb
0.1%	1,000	1,000,000
1%	10,000	10,000,000
10%	100,000	100,000,000

The chart below shows the relation between contaminant concentration and oxygen concentration. At the point where OSHA defines an atmosphere as being oxygen-deficient (19.5%), there can be as much as 70,000 ppm of a contaminant present. Many substances are deadly at far lower concentrations.

Contaminant Concentration	Oxygen Concentration
1%	(10,000 ppm) 20.7%
2%	(20,000 ppm 20.5%
3%	(30,000 ppm) 20.3%
4%	(40,000 ppm) 20.1%
5%	(50,000 ppm) 19.9%
6%	(60,000 ppm) 19.7%
7%	(70,000 ppm) 19.5%

Any displacement in the oxygen concentration is an indication there may be a contaminant present in the atmosphere.



Since oxygen comprises roughly one fifth of the normal atmosphere, a 1% displacement of oxygen means there is roughly a 5% concentration of a contaminant gas.

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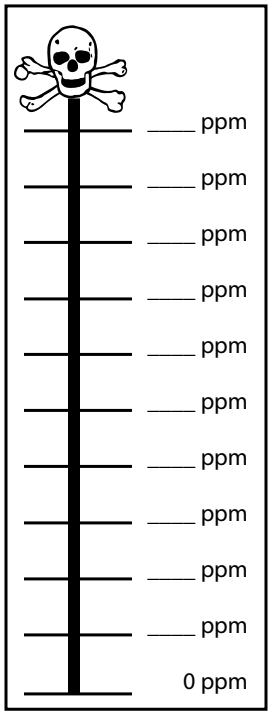
Some people like using "hazard ladders" to plot important values. Hazard ladders can help you visualize exposure limits and toxicity values in comparison to contaminant concentrations.

The hazard ladder to the right can be customized with small numbers for highly toxic materials or large numbers for less toxic materials. Determine a helpful scale from 0 ppm to the highest value you need to plot. Then plug in exposure limits, toxicity values, and meter readings as appropriate.

As with any tool, the trick is to make it work for you rather than struggle trying to fit within the confines of the tool. If there isn't enough room on the hazard ladder to plot all of values you find in your reference sources, don't worry about it. If your objective is emergency response, concentrate on IDLH and protective action criteria. If you are evaluating workplace exposure levels instead, concentrate on those values.

Hazard ladders can help you visualize exposure limits and toxicity values in comparison to contaminant concentrations.

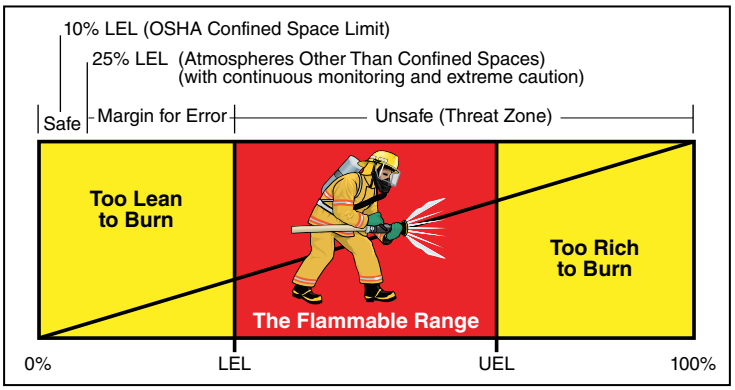


A generic hazard ladder can be customized as needed.

Evaluating Flammability

The concentration of a gas or vapor in air is also important when evaluating flammability. The most important value in this case is the **lower explosive limit (LEL)**. Below the LEL, vapors are too lean to burn. Above the upper explosive limit (UEL), vapors are too rich to burn. From the LEL to the UEL, ignition is possible. This is the flammable range.

Only atmospheres that are well below the LEL are safe to enter. Consequently, many response agencies have SOPs or SOGs that prohibit working in an atmosphere greater than 10% of the LEL. (That's 10% of the LEL, not a 10% contaminant concentration in the atmosphere.) In part, this comes from OSHA regulations that prohibit working in *confined spaces* with more than 10% of the LEL. However, when the environment does not meet the definition of a confined space, it may be acceptable for responders to keep working up to 25% of the LEL if they use continuous monitoring and extreme caution.



The 25% guideline comes from the 1985 DHHS (NIOSH) Publication No. 85-115 prepared jointly by NIOSH, OSHA, USCG, and EPA. However, it is a general guideline only, developed with hazardous waste sites in mind, and must not be used as a substitute for department SOPs or SOGs, more specific information from appropriate reference sources, or more recent federal, state, and local regulations.

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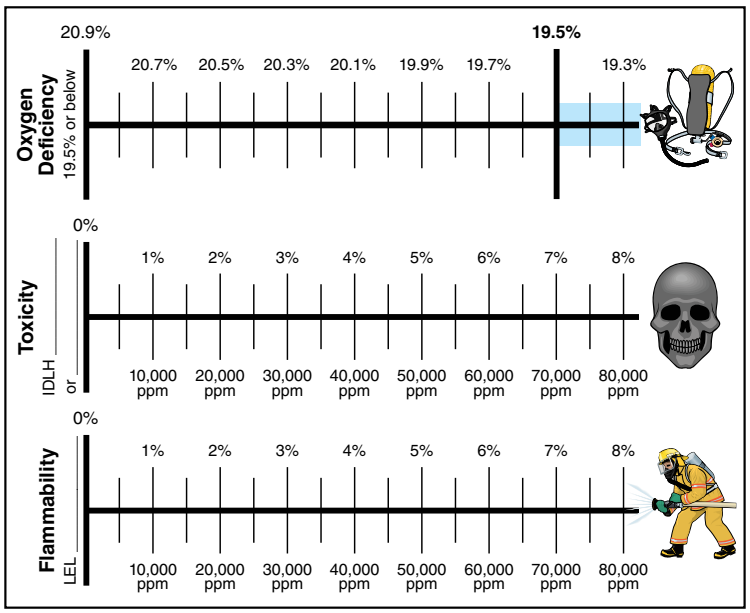
It is essential to leave a good margin of error to guard against fluctuations in the chemical concentration, delays in meter response time (lag time), defective monitors, errors in interpreting the meter readings, and other concerns. When in doubt, use the 10% LEL limit.

Also important is flash point—the minimum temperature at which a liquid produces enough vapors to form an ignitable mixture in air. Flash point is generally considered to be the most important temperature in assessing the hazards of flammable and combustible liquids. The lower the flash point, the greater the hazard.

Evaluating the Three Risks Together

For people who are visually oriented, plotting all three threats on parallel hazard ladders can help show which threat may be encountered first.



The **oxygen-deficiency** hazard ladder contains a shaded section that represents the threat zone. The **toxicity** hazard ladder reflects IDLH (immediately dangerous to life and health), but it could be modified to reflect other values as needed. The **flammability** hazard ladder shows only LEL, not UEL, because it's vital to stay well below the LEL.

Caution: Looking only at numbers on a hazard ladder can be misleading. You must also consider other relevant factors, such as how much of an escape window you have if something goes wrong.

- An LEL atmosphere presents an immediate risk if vapors ignite.
- An IDLH atmosphere provides an escape window of up to 30 minutes, although immediate exit is encouraged.
- An oxygen-deficient atmosphere has an extended escape window with a good safety margin at the OSHA limit of 19.5%. (Remember, however, this gives no information about the hazards of any contaminants present.)

Plotting all three threats on parallel hazard ladders can help show which threat may be encountered first.

Responders must also consider other relevant factors, such as how much of an escape window they have if something goes wrong.

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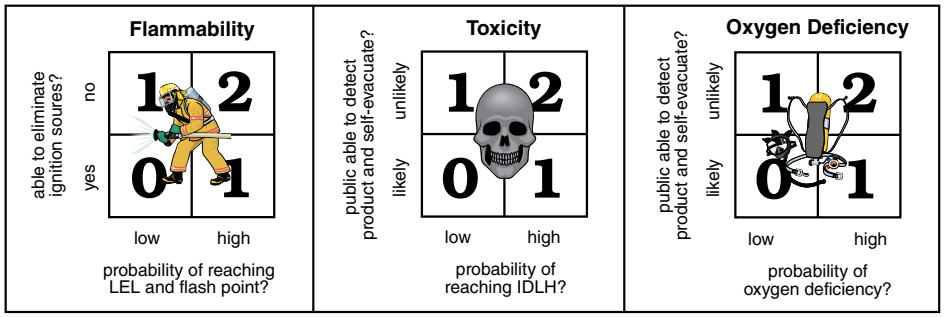
A simple **decision matrix** that weighs probability of risk against potential consequences is another good tool that can be easily adapted to evaluate the dangers associated with flammability, toxicity, and oxygen deficiency.

This simple decision matrix can be used in many ways to evaluate the probability and consequence of risk. The example below was designed to identify which threat would trigger protective actions, but it could be edited to reflect other concerns. The threat with the highest score is likely your first priority.



Each matrix looks at the probability of reaching the threat zone. The flammability matrix then looks at whether you can eliminate ignition sources. The other two matrices look at whether people are likely to detect the product and self-evacuate. (Or if people don't know the risks, are they likely to sense a chemical release and either evacuate on their own or call 911 and be directed to do so?) Again, this tool is flexible enough to be edited to fit your needs.

* * *

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Jill Meryl Levy
Author and Publisher
Firebelle Productions

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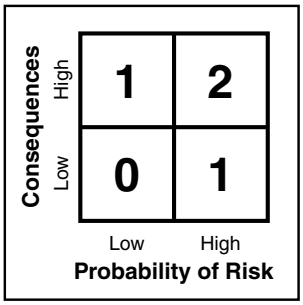
A simple decision matrix that weighs probability of risk against potential consequences can be adapted for use at a hazmat incident.



This is another tool that is flexible enough to be edited to fit the needs of the incident.

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