Diurnal Differences in Isolation and Protective Action Distances in the DOT ERG

Why are the recommended distances longer at night?

Vance Bennett
Hazardous Materials Section
California Specialized Training Institute
Governor's Office of Emergency Services

Protective Action Recommendations in the DOT ERG

The Dept. of Transportation (DOT) Emergency Response Guidebook (ERG) has recommendations for both isolation distances and protective action distances. They are found in the orange-bordered and green-bordered pages. The green-bordered pages subdivide these recommendations by day, night and spill size. Hazmat instructors often have difficulty explaining the reason for the different distances for spills in the daytime versus spills that occur at night. The 2012 DOT ERG has a brief explanation of this on page 358.

> "The list is further subdivided into daytime and nighttime situations. This is necessary due to varying atmospheric conditions which greatly affect the size of the hazardous area. The distances change from daytime to nighttime due to different mixing and dispersion conditions in the air. During the night, the air is generally calmer and this causes the material to disperse less and therefore create a toxic zone which is greater than would usually occur during the day. During the day, a more active atmosphere will cause a greater dispersion of the material resulting in a lower concentration of the material in the surrounding air. The actual area where toxic levels are reached will be smaller (due to increased dispersion)."

This document expands on that to give instructors a greater understanding of the reason for the differences between daytime and nighttime recommended protective action distances.

"varying atmospheric conditions…"

The "varying…conditions" the ERG refers to are the daily changes in atmospheric stability. These fluctuations are referred to as "diurnal" variation. (Diurnal is a meteorological term that relates to the variation in temperature between night and day.) There are other factors that can affect atmospheric stability such as cloud cover, relative humidity, wind speed, soil type and topography but the most important is heating and cooling at the earth's surface. (The recommended protective action distances in the ERG don't take the other factors into account.)

Heating and cooling at the earth's surface cause the diurnal changes of temperature in the lower atmosphere. As the sun sets the amount of radiant heat from the sun affecting the ground decreases. The ground cools rapidly as it loses its heat through radiation. The air in contact with the ground then also cools. Conditions reverse after sunrise. As the sun rises the earth's surface is heated by solar radiation.

These changes in temperature cause changes in the stability of the atmosphere near the ground. In general, when the ground cools stability increases and when the ground heats stability decreases.

"The distances change from daytime to nighttime…"

The diurnal changes in surface heating and cooling produce daily changes in atmospheric stability. (Atmospheric stability is the resistance of the atmosphere to vertical motion.) After sunset the ground cools rapidly and becomes increasingly stable. When the sun rises, the increasing solar agency striking the ground causes the temperature of the ground to increase. The air in contact with and above the ground then warms by conduction and convection from the ground. The warm air near the ground becomes more buoyant and begins to rise increasing the amount of turbulent mixing.

The stability of the atmosphere will determine the level of turbulent mixing. In general, the near-ground atmosphere is more stable at night than it is in the day. A more stable atmosphere has less turbulent mixing so a vapor/gas cloud will take longer to disperse at night. The different ERG recommendations for day and night reflect these changes in stability caused by fluctuations in air temperature between day and night. So, all other things being equal, a vapor/gas release will travel shorter distances in the day than during the night. Hence, the difference in recommended distances.

"due to different mixing and dispersion conditions…

These changes in solar radiation and atmospheric stability affect how a vapor/gas disperses, both downwind and crosswind. Wind and atmospheric turbulence move the molecules of a released vapor/gas through the air. As a vapor/gas cloud is blown downwind turbulent mixing causes it to spread out in the crosswind and downwind directions. The cloud disperses faster in an unstable atmosphere and so travels a shorter distance downwind than a cloud that is released into a more stable air mass.

"During the night, the air is generally calmer…"

After sunset the ground is no longer being heated by solar radiation. The ground will then begin to lose heat by radiation, conduction and convection. (The ground conducts hear faster than the air and therefore cools much more quickly.) The layer of air closest to the ground eventually becomes cool (cooler than the air above) and heavier by conduction. A slight temperature inversion is created which reduces the vertical movement of the air above the ground. Within a few hours after sunset, turbulent mixing is suppressed. The result is a calmer and more stable air mass.

"During the day, a more active atmosphere will cause a greater dispersion…"

Turbulent mixing will increase in an unstable atmosphere (i.e. during daylight hours). This will cause a vapor/gas cloud to disperse more quickly than it would in a more stable atmosphere (i.e. at night). This turbulence causes air to be stirred into the cloud, diluting it and dispersing it. As the cloud disperses the concentration of the vapor/gas in the air decreases.

Summary

There are a variety of factors that affect how a vapor/gas release will disperse. One of the most important is atmospheric stability. The most important factor affecting atmospheric stability is the time of day. A vapor/gas cloud will disperse faster in an unstable atmosphere than in a stable atmosphere. A vapor/gas cloud that disperses faster will travel a shorter distance than one that disperses more slowly. So, the ERG will recommend shorter isolation and protective distances for daytime releases than it will for releases that occur at night.