Ask Dr. ALOHA:

Why is ALOHA Different From the Green Book?

Francisco, a chemical engineer in Mexico City, recently attended a training class to learn the step-by-step hazard analysis procedures described in the *Technical Guidance for Hazards Analysis*[1], known as the "Green Book." Later, he used ALOHA to run the same release scenarios that had been demonstrated in his class. He was surprised to find that the vulnerable zone distances that he obtained by following the *Technical Guidance* procedures were often quite different from the footprint lengths he obtained from ALOHA. Why? he asked.

In fact, ALOHA's calculations differ from those recommended by the *Technical Guidance* in some important ways. And because CAMEO, in its Scenarios stack (on a Macintosh) and Screening & Scenarios database (in DOS), incorporates the *Technical Guidance* procedures in automated form, results that you obtain from ALOHA and CAMEO can differ as well.

Liquid evaporation

For two reasons, you are likely to see significant differences in your results for any pool evaporation case. First, the *Technical Guidance* uses a simple equation that accounts for wind speed, quantity of spilled liquid, and the chemical's molecular weight, boiling point, and vapor pressure at 20°C (68° F). ALOHA, in contrast, uses a complex method to model evaporation, accounting for the effects of wind speed, atmospheric turbulence, air temperature and pressure, and viscosity, and for additional properties of the spilled chemical as well. ALOHA accounts for the effects on pool temperature of solar heating, evaporative cooling, and several other ways in which heat is exchanged between a pool and its environment. It expects pool temperature to directly influence evaporation rate. It accounts for changes in pool temperature and hence in evaporation rate over time. The *Technical Guidance* method does not account for any of these factors; pool temperature is expected to remain constant at 20° C (68° F).

---

[1]This handbook was prepared by the U. S. Environmental Protection Agency, the Federal Emergency Management Agency, and the U. S. Department of Transportation to provide direction to people required to perform the hazard analyses described in Title III of the Emergency Planning and Community Right-to-Know Act (EPCRA), also known as the Superfund Amendments and Reauthorization Act of 1986 (SARA). To request a copy, call the Emergency Planning and Community Right-to-Know Hotline (800/535-0202 or 703/412-9877, or fax 703/413-3333, 8:30 a.m. to 7:30 p.m., Mon. - Fri.)

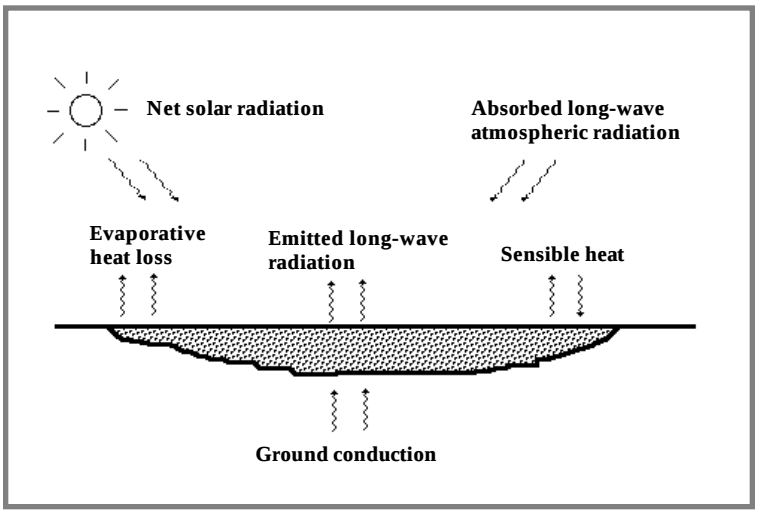

Figure 1. Some factors that influence ALOHA's evaporation rate estimates.

Second, pool area strongly influences evaporation rate. When all else is equal, the larger a pool's area, the greater will be its evaporation rate. ALOHA expects a pool of spilled liquid to spread out until its depth averages 0.5 centimeter (it then expects the pool to become thinner as it evaporates). In contrast, the *Technical Guidance* assumes that an evaporating pool will spread to a depth of 1.0 centimeter. So, given the same mass of spilled liquid, ALOHA will expect an evaporating pool to have twice as large an area as is assumed in the *Technical Guidance*.

Atmospheric dispersion

Whether a released chemical is a liquid or gas, there are several other reasons why you may obtain different results from ALOHA and the *Technical Guidance*. First, when ALOHA uses its heavy gas dispersion module, you may see a significant difference between the length of ALOHA's footprint and the vulnerable zone distance that you obtain using the *Technical Guidance* method for the same chemical and release conditions. ALOHA generally expects a chemical to disperse as a heavy gas if either the chemical is heavier than air or the cloud is so cold that it is much denser than air (regardless of the chemical's molecular weight), and if the chemical escapes in large enough quantities to form a heavy gas cloud[2]. The *Technical Guidance* method, in contrast, uses the Gaussian dispersion equation for all chemicals (this assumes that all chemicals are neutrally buoyant and are dispersed passively by the wind and atmospheric turbulence). On the right in Figure 2 below, ALOHA used its heavy gas calculations to estimate a footprint for a chlorine release. This footprint is markedly shorter than the radius of the vulnerable zone for the same release, shown on the left in Figure 2. (Note that a vulnerable zone is plotted as a circle

[2] To find out whether ALOHA has treated a particular release as a case of heavy gas dispersion, check for the notation, "Model Run: Heavy Gas" on ALOHA's Text Summary screen.

since wind could come from any direction; the zone's radius represents the distance to a Level of Concern concentration, or LOC. ALOHA's footprint, in contrast, is plotted as an ellipse oriented along a particular wind direction; the length of this ellipse represents the LOC distance.)

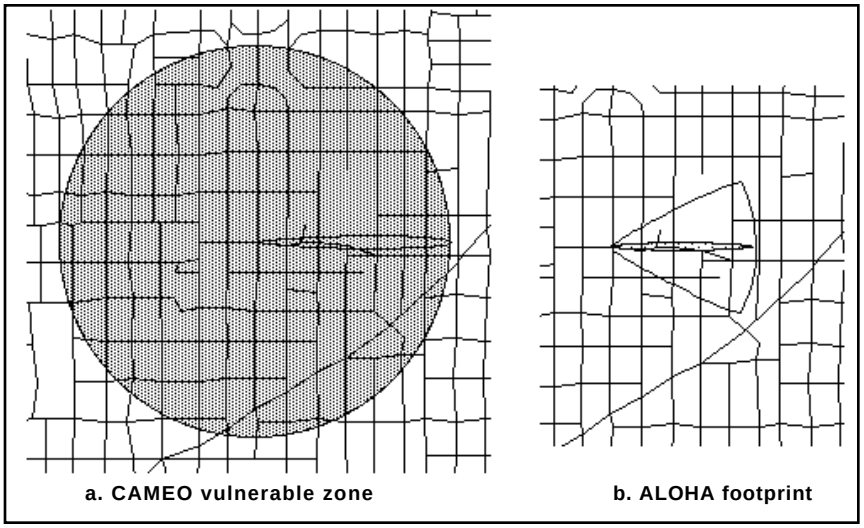

Figure 2. a. Vulnerable zone plotted from CAMEO on a MARPLOT map for chlorine, released at a rate of 3 pounds per minute under worst-case weather conditions. b. ALOHA's heavy gas footprint for the same release, plotted on the same map. Level of Concern is 0.0073 grams per cubic meter, as recommended in the *Technical Guidance*. Map scale is 1 inch = 0.25 miles.

For neutrally buoyant gases released from ground level at a continuous, constant rate, both ALOHA and the *Technical Guidance* method use the simple Gaussian formula (shown as Equation 15 on page G-3 of the *Technical Guidance*) to estimate downwind distance to an LOC[3]. The authors of the *Technical Guidance* have used this formula to predict LOC distance for many combinations of LOC, release rate, and weather conditions. Their results are shown as tables of vulnerable zone distances (Exhibits 3-1 to 3-4 in the *Technical Guidance*). When using these tables, if your LOC falls between two tabled values, you're directed to use the lowest of these two values as your LOC, then to find the vulnerable zone distance that corresponds to this value (Figure 3). Likewise, when the rate of release (QR) value that you're using falls between two QR values in the table, you're directed to use the tabled QR value that's closest to your original value. Because ALOHA

[3] The Gaussian model that's incorporated in ALOHA is more complex than the simple *Technical Guidance* equation. It includes equations to account for release rates that change over time, and it includes a third plume size factor, s_x, to account for dispersion in the along-wind direction caused by processes such as wind shear. But ALOHA's model reduces to the simple equation shown in the *Technical Guidance* when release rate is constant and continuous, the release is from ground level, and the gas cloud is neutrally buoyant.

makes exact calculations rather than using tabled values, the length of its footprint can differ substantially from the vulnerable zone distance for the same release case. (Because CAMEO also makes exact calculations, CAMEO users can find that their results differ substantially from those they obtain using the *Technical Guidance* tables.)

QR (pounds/minute)	LOC (grams/cubic meter) 0.001	0.002
1	1.3	0.9
2	2.1	1.3
3	2.9	1.7
4	3.7	2.1
5	4.5	2.5
8	7.1	3.7
10	9	4.5
15	*	6.7
20	*	9
25	*	*

Figure 3. A portion of Exhibit 3-1, showing vulnerable zone distance (in miles) under worst-case conditions, for a given LOC and QR. If the LOC for a chemical is 0.0015 and QR is 5 pounds per minute, the *Technical Guidance* recommends using 0.001 grams per cubic meter as your LOC, giving a distance of 4.5 miles. Using the exact LOC instead would give a distance of 3.2 miles.

For cases of neutrally buoyant gas dispersion, both ALOHA and the *Technical Guidance* use equations containing numbers called the "Briggs dispersion coefficients" to estimate two plume size factors, s_y and s_z, which describe the vertical and crosswind extent of a dispersing gas cloud. The equations used in the *Technical Guidance* are shown in Exhibit G-1. In contrast, whether conditions are urban or open-country (rural), ALOHA uses only the open-country equations for s_y shown in Exhibit G-1. This is because the coefficients for urban conditions are based in part on measurements averaged over 1 hour, while the open-country coefficients for s_y are based on measurements that were averaged over about 3 minutes. ALOHA's developers believe the shorter sampling durations associated with the open-country measurements to be more appropriate for most accidental releases. Because s_z is a function mostly of ground roughness, it is estimated in ALOHA using the same equations that you see in Exhibit G-1. Because of this use of different coefficients for s_y for urban dispersion, ALOHA's footprint for an urban case can sometimes be much longer than the vulnerable zone distance that you obtain by following the *Technical Guidance*.

Other differences

There are two other important differences between ALOHA and the *Technical Guidance* procedure. First, you've probably noticed that ALOHA will not estimate downwind concentrations at distances further than 10 kilometers (6 miles) from the release point, and that very long footprints are truncated at 10 kilometers. The *Technical Guidance* uses a different cut-off distance of 10 miles (16 kilometers). One reason for applying a cut-off distance is because important weather conditions, such as wind speed and direction and atmospheric turbulence, are likely to change substantially far from the release point. The exact location of an appropriate cut-off distance – whether 10 or 16 kilometers, or another value – is very much a matter of judgment.

Second, ALOHA's chemical library contains no solids and no liquids that have very low vapor pressures under ambient conditions, because these substances are not expected to be volatile enough to be air dispersion hazards. In contrast, the *Technical Guidance* describes how to estimate dispersion of any substance that has been designated an "Extremely Hazardous Substance" under U. S. law. Such "EHS" substances include not only many chemicals that are present in ALOHA's library, but also liquids of very low volatility, such as sulfuric acid, and solids, such as cobalt and lindane.

A difference in purpose

You may wonder why these substantial differences between ALOHA and the *Technical Guidance* procedures exist. The reason for the differences in calculation methods is a fundamental difference in purpose. The *Technical Guidance* is a method that you can use to quickly distinguish the highest-priority hazards within a community from hazards that pose much less of a threat to residents. It relies on the simplest possible calculations, in order to be useful to those who have no other resources to use, such as a computer or even a calculator. You can use this approach and obtain results when you have only three or four pieces of information about a stored chemical.

ALOHA, on the other hand, is intended to give you as accurate an estimate as possible of the extent and location of the area that might be placed at risk by a particular accidental chemical release. Many factors can influence how hazardous a particular release might be. These include: meteorological conditions such as wind speed, air temperature, and relative humidity; physical properties of the chemical, such as vapor pressure, boiling point, and molecular weight; and storage and release conditions, such as the dimensions of a storage tank, storage temperature and pressure, and size of a tank rupture. ALOHA accounts for many more of these factors than does the *Technical Guidance.* You need to enter much more information into ALOHA than you need to estimate the size of a vulnerable zone using the *Technical Guidance.* For this reason, it would be difficult to use ALOHA to initially distinguish between higher- and lower-priority chemical hazards in a community, while the *Technical Guidance* procedure has been developed as a way to make just such initial assessments.

But once you have completed your initial screening and are ready to examine in greater detail the potential hazards to a community posed by high-priority chemical facilities, you may find ALOHA to be a useful tool.

Prepared by: Modeling and Simulation Studies Branch, Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration, Seattle, WA 98115