Let's Take a PEEK at the PEAC Software

PEAC Example –Sulfur Dioxide

by S. Bruce King

This month our example is Sulfur Dioxide, which has a chemical formula of SO_2. Sulfur Dioxide is listed under the UN # (United Nations Number) by the US Department of Transportation: UN 1079 and has a CAS # of 7446-09-5.

Persons exposed only to sulfur dioxide gas pose no risk of secondary contamination. Persons whose skin or clothing is contaminated with liquid sulfur dioxide can secondarily contaminate rescuers by direct contact or through off gassing of vapor. At room temperature, sulfur dioxide is a nonflammable, colorless gas that is heavier than air. Its strong, pungent odor and irritating properties usually provide adequate warning of its presence.

Sulfur dioxide is severely irritating to the eyes, mucous membranes, skin, and respiratory tract. Bronchospasm, pulmonary edema, pneumonitis, and acute airway obstruction can occur.

Inhalation exposure to very low concentrations of sulfur dioxide can aggravate chronic pulmonary diseases, such as asthma and emphysema. Certain highly sensitive asthmatics may develop bronchospasm when exposed to sulfur dioxide or sulfite-preserved foods.

Sulfur dioxide reacts with water in the upper airway to form sulfurous acid, bisulfite, and sulfite, all of which induce irritation. As a result, reflex bronchoconstriction increases airway resistance.

Physical Properties

Description: colorless gas at room temperature, colorless liquid when pressurized or cooled.

Molecular weight: 64.06

Boiling point: (760 mm Hg): 14.0 °F (-10.0 °C)

Freezing point: -99.4 °F (-72.7 °C)

Vapor pressure: 2,538 mm Hg at 70.0°F (21.1 °C)

Vapor density: 1.43 g/mL (water = 1.00)

Water solubility: soluble in water (11.3 g/100 mL at 68 °F [20 °C])

Flammability: nonflammable

Description At room temperature, sulfur dioxide is a nonflammable, colorless gas with a very strong, pungent odor. Most people can smell sulfur dioxide at levels of 0.3 to 1 ppm. It is handled and transported as a liquefied compressed gas. It easily dissolves in water. The liquid is heavier than water. Although sulfur dioxide does not burn in air, cylinders of compressed liquid can explode in the heat of a fire, i.e., the tanks can BLEVE.

Sources/Uses Sulfur dioxide gas is released primarily from the combustion of fossil fuels (75% to 85% of the industrial sources), the smelting of sulfide ores, volcanic emissions, and several other natural sources. It is a U.S. EPA priority air pollutant, but has many industrial and agricultural uses. It is sometimes added as a warning marker and fire retardant to liquid grain fumigants. Approximately 300,000 tons are used each year to manufacture hydrosulfites and other sulfur-containing chemicals; to bleach wood pulp and paper; to process, disinfect, and bleach food; for waste and water treatment; in metal and ore refining; and in oil refining. Toxic amounts of sulfur dioxide can be released from the preservative chemical metabisulfite in the presence of water and acid.

Synonyms include sulfur oxide, sulfurous acid anhydride, sulfurous anhydride, and sulfurous oxide.

Standards and Guidelines

OSHA PEL (permissible exposure limit) = 5 ppm (averaged over an 8-hour workshift)

NIOSH IDLH (immediately dangerous to life or health) = 100 ppm

AIHA ERPG-2 (maximum airborne concentration below which it is believed that nearly all persons could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action) = 3 ppm

Incompatibilities Sulfur dioxide dissolves in water or steam to form sulfurous acid. Liquid sulfur dioxide corrodes iron, brass, copper, and some forms of plastic and rubber. Many metals, including zinc, aluminum, cesium, and iron, incandesce and/or ignite in unheated sulfur dioxide. Sulfur dioxide reacts explosively when it comes in contact with sodium hydride. Sulfur dioxide ignites when it is mixed with lithium acetylene carbide diamino or lithium acetylide ammonia.

Acute Exposure Sulfur dioxide dissolves in the moisture on skin, eyes, and mucous membranes to form sulfurous acid, an irritant and inhibitor of mucociliary transport. Most of the inhaled sulfur dioxide is detoxified by the liver to sulfates and excreted in the urine. The bisulfite ion produced when sulfur dioxide reacts with water is likely to be the main initiator of sulphur dioxide-induced bronchoconstriction. Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Respiratory - Sulfur dioxide respiratory irritation induces symptoms such as sneezing, sore throat, wheezing, shortness of breath, chest tightness, and a feeling of suffocation. Reflex laryngeal spasm and edema can cause acute airway obstruction. Bronchospasm, pneumonitis, and pulmonary edema can occur. Some individuals are very susceptible to the presence of sulfur dioxide and overreact to concentrations which, in most people, elicit a much milder response. This hyperreactive response occurs the first time the individual is exposed and is therefore not an acquired immune or "hypersensitivity" response. Acclimatization (a physiological adjustment of the individual to environmental changes) may also occur in up to 80% of exposed individuals. This is not necessarily beneficial although exposure may become less subjectively objectionable upon continuous or repeated exposure. Asthmatics who are sensitive to sulfites in food can develop bronchospasm or an anaphylactoid reaction. Sulfur dioxide, along with other components of air pollution, can exacerbate chronic cardiopulmonary disease.

Exposure to high concentrations of sulfur dioxide can lead to Reactive Airway Dysfunction Syndrome (RADS), a chemically- or irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the relatively smaller diameter of their airways. Children also may be more vulnerable because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Dermal Sulfur dioxide is a severe skin irritant causing stinging pain, redness, and blisters, especially on mucous membranes. Skin contact with escaping compressed gas or liquid sulfur dioxide can cause frostbite and irritation injury. Because of their relatively larger surface area: body weight ratio, children are more vulnerable to toxicants that affect the skin.

Ocular Conjunctivitis and corneal burns can result from the irritant effect of sulfur dioxide vapor or escaping compressed gas, and from direct exposure to the liquid.

Gastrointestinal Nausea, vomiting, and abdominal pain have been reported after inhalation exposure to moderate to high doses of sulfur dioxide.

Potential Sequelae High-level acute exposures have resulted in pulmonary fibrosis, chronic bronchitis, and chemical bronchopneumonia with bronchiolitis obliterans. Bronchospasm can be triggered in individuals who have underlying lung disease, especially those who have asthma and emphysema. Rarely, new onset airway hyperreactivity, known as reactive airways dysfunction syndrome (RADS), develops in patients without prior bronchospasm.

Chronic Exposure can result in an altered sense of smell (including increased tolerance to low levels of sulfur dioxide), increased susceptibility to respiratory infections, symptoms of chronic bronchitis, and accelerated decline in pulmonary function. Chronic exposure may be more serious for children because of their potential longer life span.

Carcinogenicity The International Agency for Research on Cancer (IARC) assigned sulfur dioxide to Group 3, not classifiable as to its carcinogenicity to humans.

Reproductive and Developmental Effects - Sulfur dioxide is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences. There are no known reproductive or developmental effects of sulfur dioxide alone by any route of exposure. There is no conclusive evidence that sulfur dioxide is a genotoxin in humans.

In using the PEAC application we access information for the chemical by first locating Sulfur Dioxide in the database. The following figures show the screens displayed for chemical properties, Figure 1 for the *PEAC-WMD for Windows* application and Figure 2-5 for the *PEAC-WMD for the Pocket PC* application.

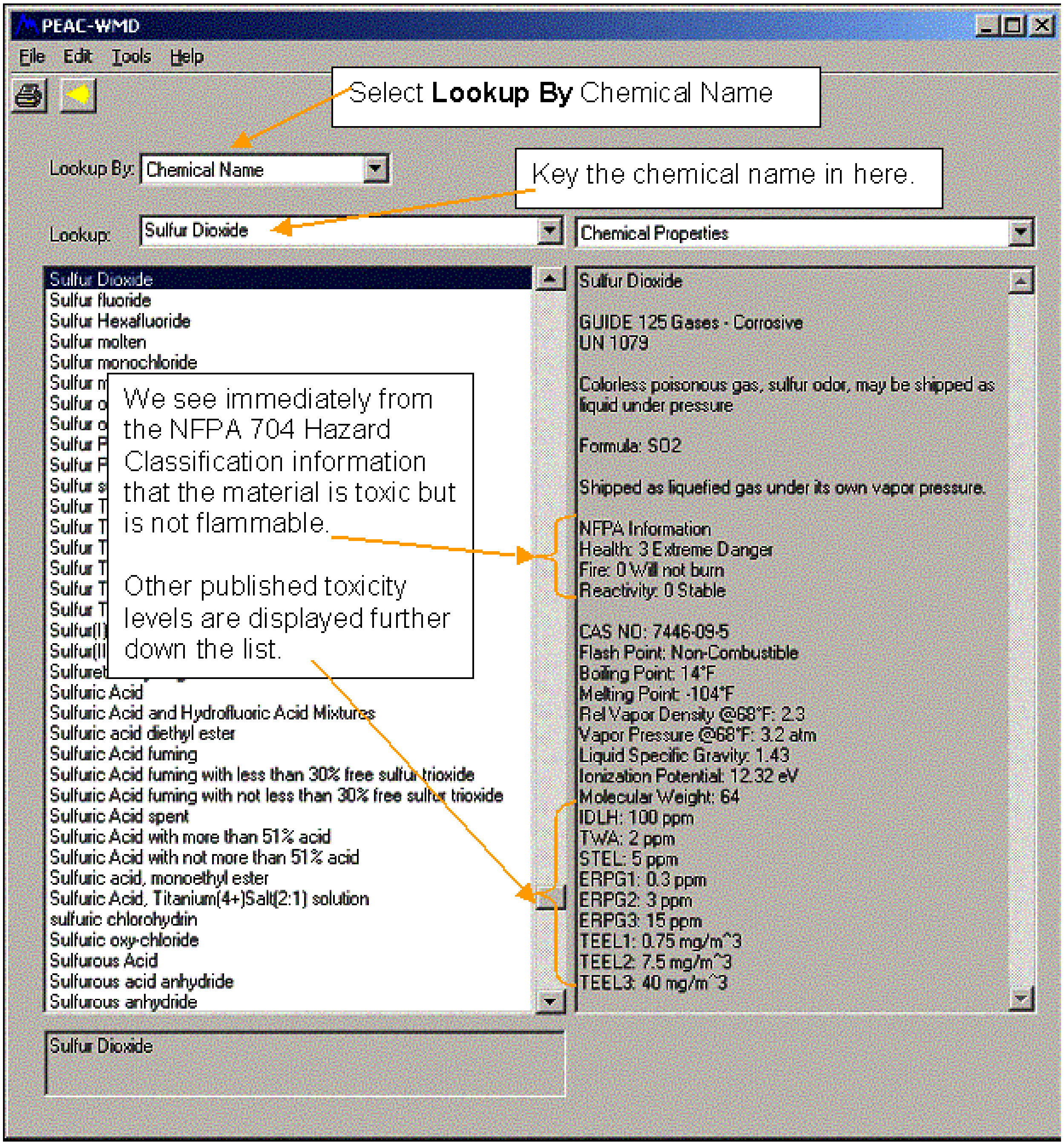


Figure 1 - Using the Lookup By: Name for Sulfur Dioxide using the PEAC-WMD for Windows application

Review of the information displayed in the chemical properties screen whether in Figure 1 (above) or Figures 2-4 (below), show chemical properties values discussed earlier at the top of this discussion. As you can see, the published toxicity values, e.g., IDLH and the TEELs (Temporary Emergency Exposure Limits) published by Department of Energy are provided. We will use the IDLH as the Level of Concern when we develop the PAD a little later.

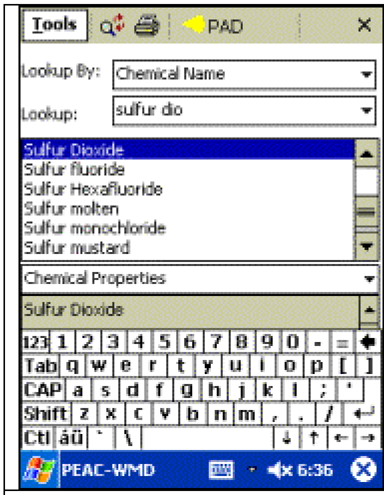


Figure 2 – Selecting Sulfur Dioxide using the PEAC-WMD for Pocket PC application

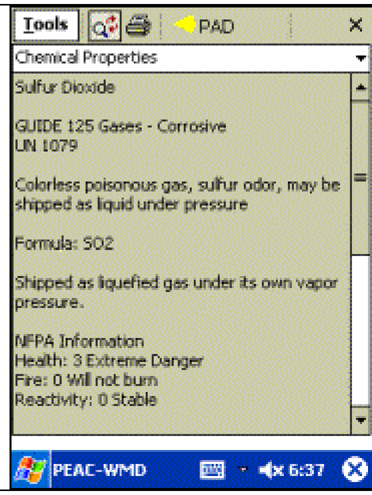


Figure 3 – The top portion of the Chemical Properties Data Display Screen

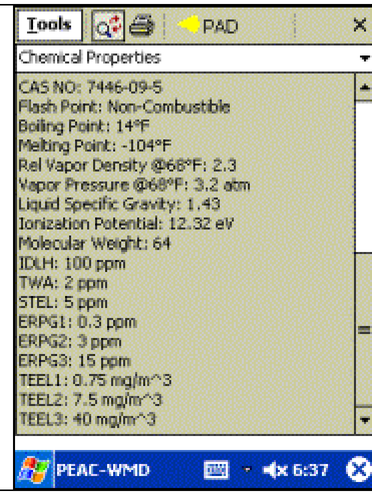


Figure 4– The bottom portion of the Chemical Properties Data Display Screen

The PEAC-WMD application provides more than just the **Chemical Properties** for the identified material, the **Chemical Properties** are just the default information screen displayed, by clicking (if running the Windows version, see Figure 5) or tapping (if running the Pocket PC version, see Figure 6) on the drop-down box where **Chemical Properties** is displayed on the screen, the user is provided with a list of other databases that provide information for the selected chemical (Sulfur Dioxide in our current example). So the search is done once, and the user is indexed into the different databases easily and quickly.

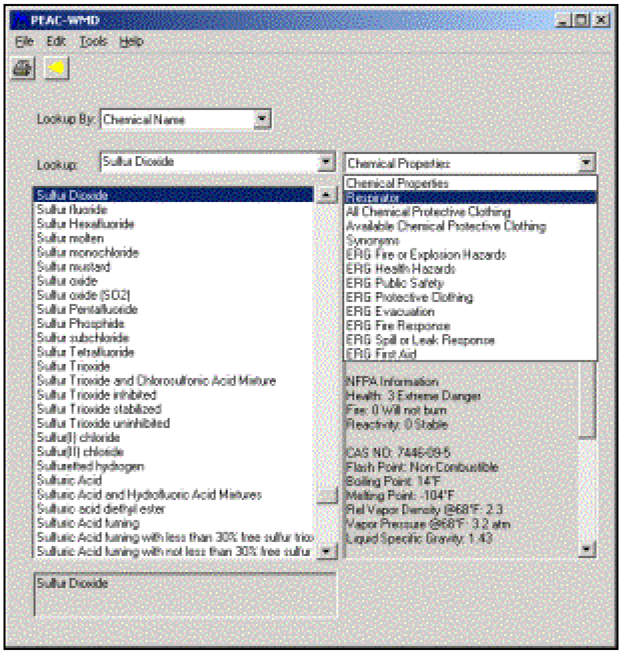


Figure 5 – Accessing other databases from the PEAC-WMD for Windows application

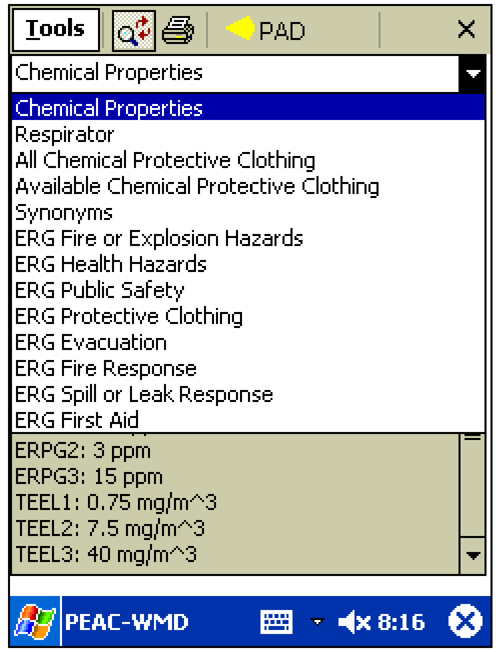


Figure 6 – Accessing other databases from the PEAC-WMD for Pocket PC application

A quick review or sampling of the type of information available in each of these screens is now provided. First is access to **Respirators Recommendations**, these are primarily taken from the NIOSH Pocket Guide and provide the user with different types of respirators for increasing concentrations. A sample of the information is provided in Figure 7. Likewise the **Chemical Protective Clothing (CPC)** database can be accessed by clicking on either the **All Chemical Protective Clothing** or the **Available Chemical Protective Clothing** selection as shown in Figure 8. The **All Chemical Protective Clothing** displays all the CPC entries in the PEAC-WMD database for the selected chemical vs. the **Available Chemical Protective Clothing** displays just those CPC entries that match the manufacturers the user has previously identified as the products the response organization typically keeps in inventory.

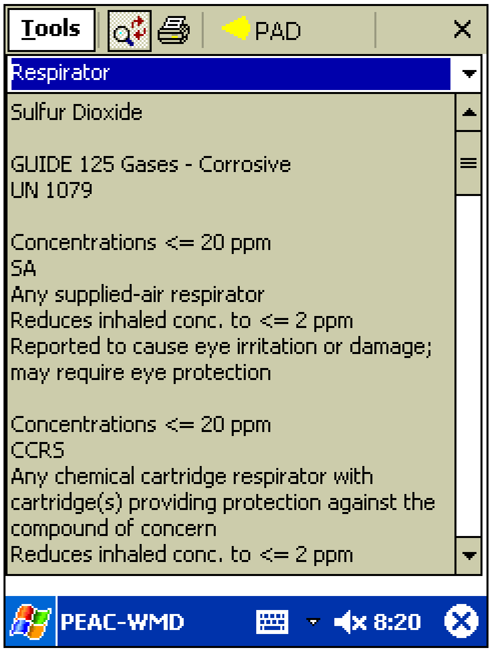


Figure 7 – Respirator Recommendations for Sulfur Dioxide

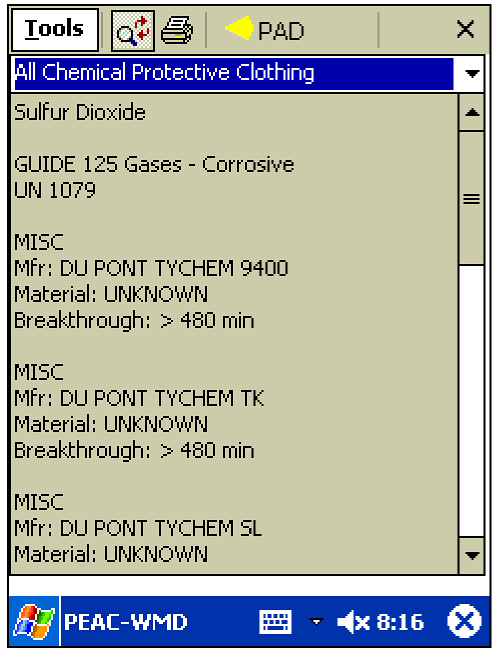


Figure 8 – Chemical Protective Clothing for Sulfur Dioxide

The IC (Incident Commander) will typically utilize more than a single resource for developing a response plan but sometimes the information in other resources will use a different name for the same substance. Clicking on the **Synonyms** selection will provide a quick list of other names the substance may be referenced by in other resources as shown in Figure 9. To further assist the responder in initiating the best response plan, PEAC-WMD also provides the generic guidelines found in the 'orange pages' of the DOT Emergency Response Guidebook (ERG). These are categorized into different types of procedures depending on the incident and the problem to be mitigated. An example for **Spill or Leak Response** is shown in Figure 10.

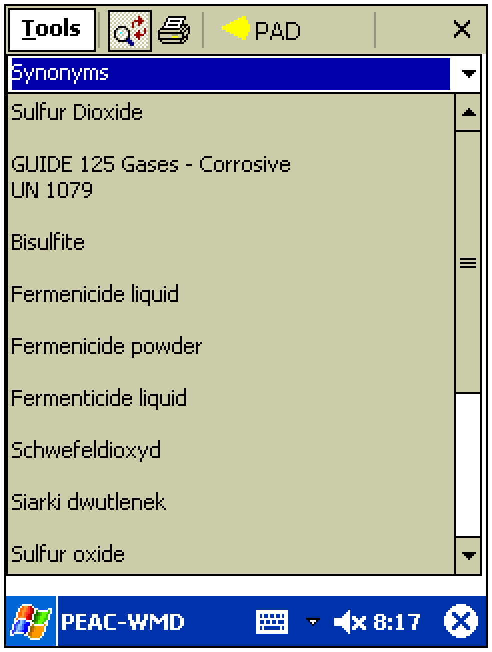


Figure 9 – Synonyms

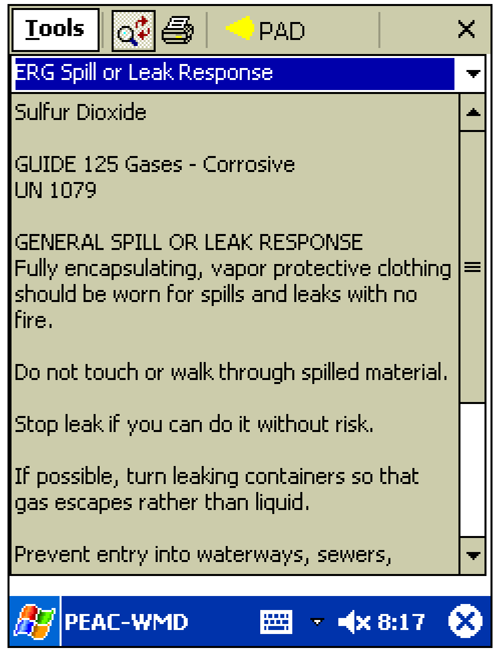
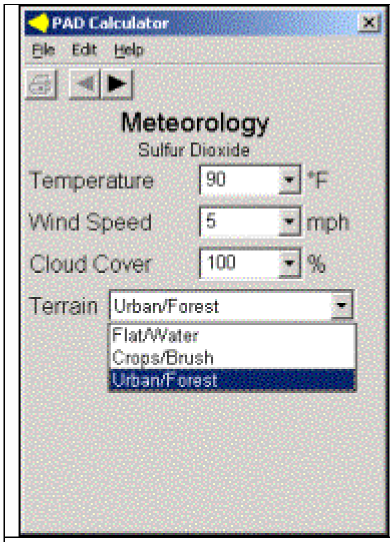


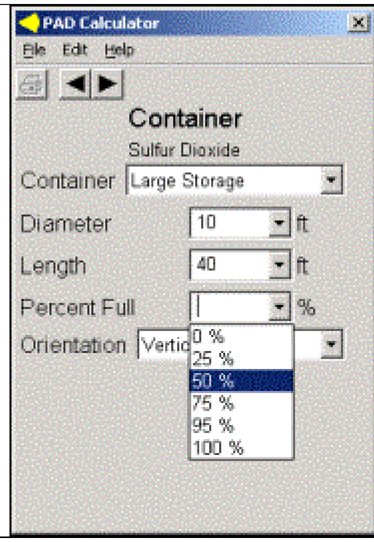
Figure 10 – ERG Spill or Leak Response

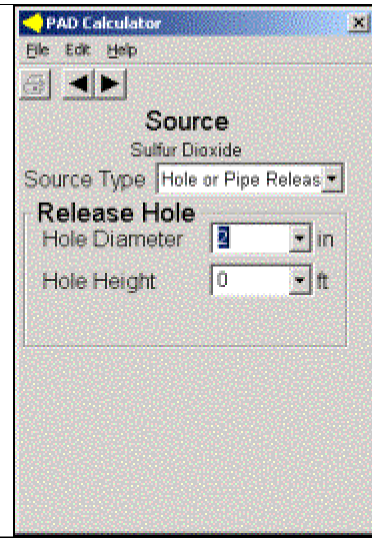
A benefit of using the PEAC tool is assistance in the development of an evacuation zone for those chemicals that produce a toxic vapor cloud. Because of its boiling point Sulfur Dioxide will be released from a container as a vapor or aerosol or a liquid that will rapidly vaporize. As with all of our examples, AristaTek creates a scenario for a spill or release of the specific chemical, and then we work through the development of a PAD (Protective Action Distance) to demonstrate how the PEAC system works.

For our hypothetical scenario using Sulfur Dioxide as the involved chemical we'll set the location to be a manufacturing facility outside of St. Louis. A new hired driver of a fork lift has driven beneath a Sulfur Dioxide storage tank and clipped a 2' valve which is now venting liquid and vapor from the bottom of the tank. The tank is mounted vertically, 10 foot in diameter, 40 foot long, and about 50% full of material. The time is 8:30 AM on August 12th, the temperature is 90°F with overcast skies and winds are about 5 mph. There are manufacturing and commercial areas nearby and light traffic on a nearby highway downwind. The PEAC tool can provide guidance with regards to toxic vapor clouds that are released.

As seen at the top of the data display screens, there is a yellow icon displayed; this is the PEAC icon for notifying the user that a Protective Action Distance can be calculated. Clicking or tapping on the PAD icon will display a screen as shown in Figure 11. Following through the screens, we provide information on the Meteorology, Container Size, and Type of Release (Source). If you decide to follow along on this example, remember to change the location to St. Louis and the time to 8:30 AM, August 12th.







Meteorology	**Container**	**Source**
It's St. Louis in August and the temperature about 90°, wind is set for 5 mph, overcast so we'll set cloud cover to 100%, and the terrain is Urban/Forest since it's an industrial setting.	We have selected from our list of container sizes the **Large Storage** selection. Then we have entered the diameter, length and set the % full to 50%. The default **Orientation** of the tank is vertical.	As the scenario calls for, we've selected **Hole of pipe Release** as the **Source** type of release. The default **Hole Diameter** and **Hole Height** we will leave unchanged at 2" and 0' respectively.

Figure 11 – Calculating a PAD using the PEAC-WMD System

By pressing the right arrow at the top of the screen, the PEAC system will display a screen as shown in Figure 12. This calculates a **PAD** (Protective Action Distance) based on the default **Level of Concern** the IDLH of 100 ppm. This evacuation or standoff distance is based on the toxicity of Sulfur Dioxide.

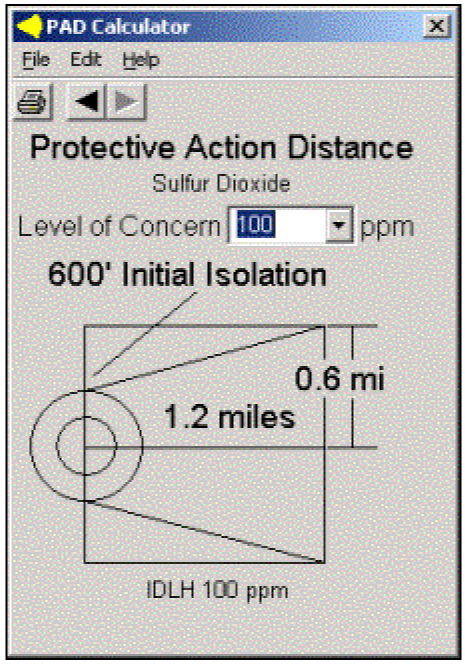


Figure 12 – Default PAD for Sulfur Dioxide-Using the IDLH of 100 ppm

One of the unique advantages of the PEAC-WMD tool is how easily the user can assess different conditions, whether it be changing the wind speed or temperature or another input value that would effect the PAD. An example is to assess the impact on evacuation or standoff distance if a different toxicity level is considered. By tapping or clicking on the down arrow on the field adjacent to the Level of Concern other established toxicity values can be selected. Figure 13 demonstrates selecting the ERPG-2 value of 3ppm.

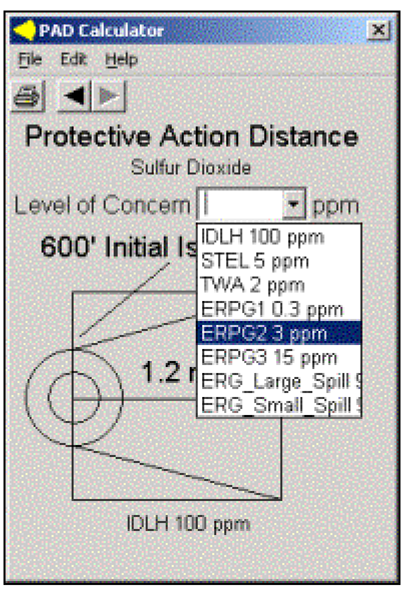


Figure 13 – Selecting a different Level of Concern

Once the value has been selected the PEAC-WMD tool will calculated a new PAD. In this example a warning message will appear since the PAD is greater than 7.0 miles (Figure 14). The PAD will be displayed once the user has acknowledged the warning message that wind speed and terrain over long distances will most likely vary.

Figure 14 – Warning message if PADs greater than 7 miles are calculated.

As shown in Figure 15, the calculated Pad is then displayed and because the concentration or **Level of Concern** has dropped from 100 ppm to 3 ppm, our distance has increased substantially.

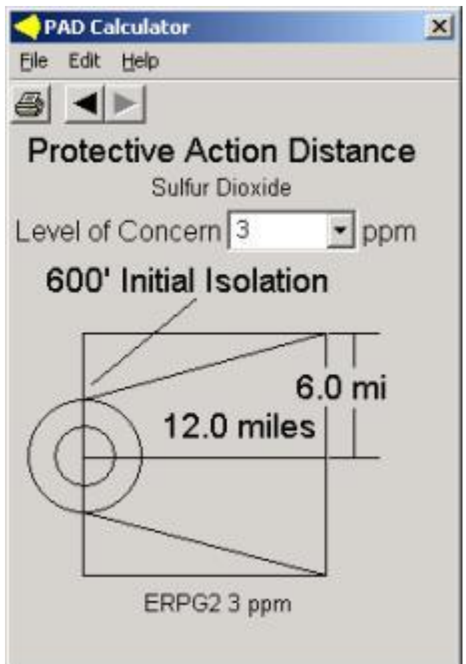


Figure 15 – PAD for 3 ppm Level of Concern

Now we can provide the IC with some guidance as to how far downwind people might be at risk.

Substantial portions of this discussion were adapted from the Agency for Toxic Substances and Disease Registry (ATSDR) Web site for Medical Management Guidelines at: http://www.atsdr.cdc.gov/.