Another look at Hydrogen Cyanide in the PEAC® Tool

We took a look at Hydrogen Cyanide in an earlier article in July 2002, but this month we've decided to take another look at this common chemical that also is very toxic. One reason was to provide additional discussion about the substance since Dr. Nordin's technical discussion this month dealt with Hydrogen Cyanide exposure and its effects that may result from fighting fires.

Persons whose clothing or skin is contaminated with cyanide-containing solutions can secondarily contaminate response personnel by direct contact or through off-gassing vapor.

Hydrogen cyanide is a colorless or pale-blue liquid at room temperature. It is very volatile, readily producing flammable and toxic concentrations at room temperature. Hydrogen cyanide gas mixes well with air, and explosive mixtures are easily formed.

Hydrogen cyanide has a distinctive bitter almond odor, but some individuals cannot detect it and consequently, it may not provide adequate warning of hazardous concentrations. Also the Hydrogen Cyanide odor might be masked by other odors.

Hydrogen cyanide is absorbed well by inhalation and can produce death within minutes. Substantial absorption can occur through intact skin if vapor concentration is high or with direct contact with solutions, especially at high ambient temperatures and relative humidity. Exposure by any route may cause systemic effects.

Description At temperatures below 78 °F, hydrogen cyanide is a colorless or pale-blue liquid (hydrocyanic acid); at higher temperatures, it is a colorless gas. Hydrogen cyanide is very volatile, producing potentially lethal concentrations at room temperature. The vapor is flammable and potentially explosive. Hydrogen cyanide has a faint, bitter almond odor and a bitter, burning taste. It is soluble in water and is often used as a 96% aqueous solution.

Sources/Uses Hydrogen cyanide is manufactured by oxidation of ammonia-methane mixtures under controlled conditions and by the catalytic decomposition of formamide. It may be generated by treating cyanide salts with acid, and it is a combustion byproduct of nitrogen-containing materials such as wool, silk, and plastics. It is also produced by enzymatic hydrolysis of nitriles and related chemicals. Hydrogen cyanide gas is a by-product of coke-oven and blast-furnace operations.

Hydrogen cyanide is used in fumigating; electroplating; mining; and in producing synthetic fibers, plastics, dyes, and pesticides. It also is used as an intermediate in chemical syntheses.

Physical Properties

Description: Colorless gas or colorless or pale-blue liquid

Warning properties: Almond odor at >I ppm; inadequate warning for acute or chronic exposure
Molecular weight: 27.03 daltons
Boiling point (760 mm Hg): 78 °F (25.6 °C)
Freezing point: 8 °F (-13.4 °C)
Specific gravity: 0.69 (water = 1)
Vapor pressure: 630 mm Hg at 68 °F (20 °C)
Gas density: 0.94 (air = 1)
Water solubility: Miscible with water
Flammability: Flammable at temperatures > 0 °F (-18 °C)
Flammable range: 5.6% to 40% (concentration in air)

Incompatibilities Hydrogen cyanide reacts with amines, oxidizers, acids, sodium hydroxide, calcium hydroxide, sodium carbonate, caustic substances, and ammonia. Hydrogen cyanide may polymerize at 122 °F to 140 °F.

Synonyms Formonitrile; Hydrocyanic acid, liquefied; Hydrogen cyanide, anhydrous, stabilized; Prussic acid.

Standards and Guidelines

OSHA PEL (permissible exposure limit) (ceiling) = 10 ppm (skin) (averaged over 15 minutes)

NIOSH IDLH (immediately dangerous to life or health) = 50 ppm

AIHA ERPG-2 (emergency response planning guideline) (maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual’s ability to take protective action) = 10 ppm.

Routes of Exposure

Inhalation - Hydrogen cyanide is readily absorbed from the lungs; symptoms of poisoning begin within seconds to minutes. The odor of hydrogen cyanide is detectable at 2–10 ppm (OSHA PEL = 10 ppm), but **does not provide adequate warning of hazardous concentrations**. Perception of the odor is a genetic trait (20% to 40% of the general population cannot detect hydrogen cyanide); also, rapid olfactory fatigue can occur. Hydrogen cyanide is lighter than air.

Children exposed to the same levels of hydrogen cyanide as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios.

Skin/Eye Contact - Exposure to hydrogen cyanide can cause skin and eye irritation. More importantly, skin or eye absorption is rapid and contributes to systemic poisoning. After skin exposure, onset of symptoms may be immediate or delayed for 30 to 60 minutes. Most cases of toxicity from dermal exposure have been from industrial accidents involving partial immersion in liquid cyanide or cyanide solutions or from contact with molten cyanide salts, resulting in large surface-area burns.

Children are more vulnerable to toxicants absorbed through the skin because of their relatively larger surface area:body weight ratio.

Health Effects

Hydrogen cyanide is highly toxic by all routes of exposure and may cause abrupt onset of profound CNS (Central Nervous System), cardiovascular, and respiratory effects, leading to death within minutes.

Exposure to lower concentrations of hydrogen cyanide may produce eye irritation, headache, confusion, nausea, and vomiting followed in some cases by coma and death.

Hydrogen cyanide acts as a cellular asphyxiant. By binding to mitochondrial cytochrome oxidase, it prevents the utilization of oxygen in cellular metabolism. The CNS and myocardium are particularly sensitive to the toxic effects of cyanide.

Acute Exposure In humans, cyanide combines with the ferric ion in mitochondrial cytochrome oxidase, preventing electron transport in the cytochrome system and bringing oxidative phosphorylation and ATP production to a halt. The inhibition of oxidative metabolism puts increased demands on anaerobic glycolysis, which results in lactic acid production and may produce severe acid-base imbalance. The CNS is particularly sensitive to the toxic effects of cyanide, and exposure to hydrogen cyanide generally produces symptoms within a short period of time.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

CNS - CNS signs and symptoms usually develop rapidly. Initial symptoms are nonspecific and include excitement, dizziness, nausea, vomiting, headache, and weakness. As poisoning progresses, drowsiness, tetanic spasm, lockjaw, convulsions, hallucinations, loss of consciousness, and coma may occur.

Cardiovascular - Abnormal heartbeat can occur in cases of severe poisoning. Slow heartbeat, intractable low blood pressure, and death may result. High blood pressure and a rapid heartbeat may be early, transient findings.

Respiratory - After systemic poisoning begins, victims may complain of shortness of breath and chest tightness. Pulmonary findings may include rapid breathing and increased depth of respirations. As poisoning progresses, respirations become slow and gasping; a bluish skin color may or may not be present. Accumulation of fluid in the lungs may develop.

Children may be more vulnerable to gas exposure because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic - An anion-gap, metabolic acidosis occurs in severe poisoning from increased blood levels of lactic acid. Because of their higher metabolic rates, children may be more vulnerable to toxicants interfering with basic metabolism.

Dermal - Dermal absorption can occur, leading to systemic toxicity. Absorption occurs more readily at high ambient temperature and relative humidity. Because of their relatively larger surface area:body weight ratio, children are more vulnerable to toxicants absorbed through the skin.

Ocular - When splashed in the eye, hydrogen cyanide can cause eye irritation and swelling. Eye contact with cyanide salts has produced systemic symptoms in experimental animals.

Potential Sequelae - Survivors of severe exposure may suffer brain damage due to a direct action on neurons, or to lack of oxygen, or possibly due to insufficient blood circulation. Cases of neurologic sequelae (secondary effects) such as personality changes, memory deficits, disturbances in voluntary muscle movements, and the appearance of involuntary movements (i.e., extrapyramidal syndromes) have been reported.

Chronic Exposure Chronically exposed workers may complain of headache, eye irritation, easy fatigue, chest discomfort, palpitations, loss of appetite, and nosebleeds. Chronic exposure may be more serious for children because of their potential longer life span.

Carcinogenicity Hydrogen cyanide has not been classified for carcinogenic effects, and no carcinogenic effects have been reported for hydrogen cyanide.

Reproductive and Developmental Effects - No reproductive or developmental effects of hydrogen cyanide have been reported in experimental animals or humans. Hydrogen cyanide 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.

Increased levels of thiocyanate in the umbilical cords of fetuses whose mothers smoked compared to those whose mothers were non-smokers suggests that thiocyanate, and possibly also cyanide, can cross the placenta. No data were located pertaining to hydrogen cyanide in breast milk.

In using the PEAC application we access information for the chemical by first locating Hydrogen Cyanide in the database. The following figures show the screens displayed for chemical properties, Figure 1-2 for the *PEAC-WMD™ for Windows* application and Figure 3-7 for the *PEAC-WMD for the Pocket PC* application.

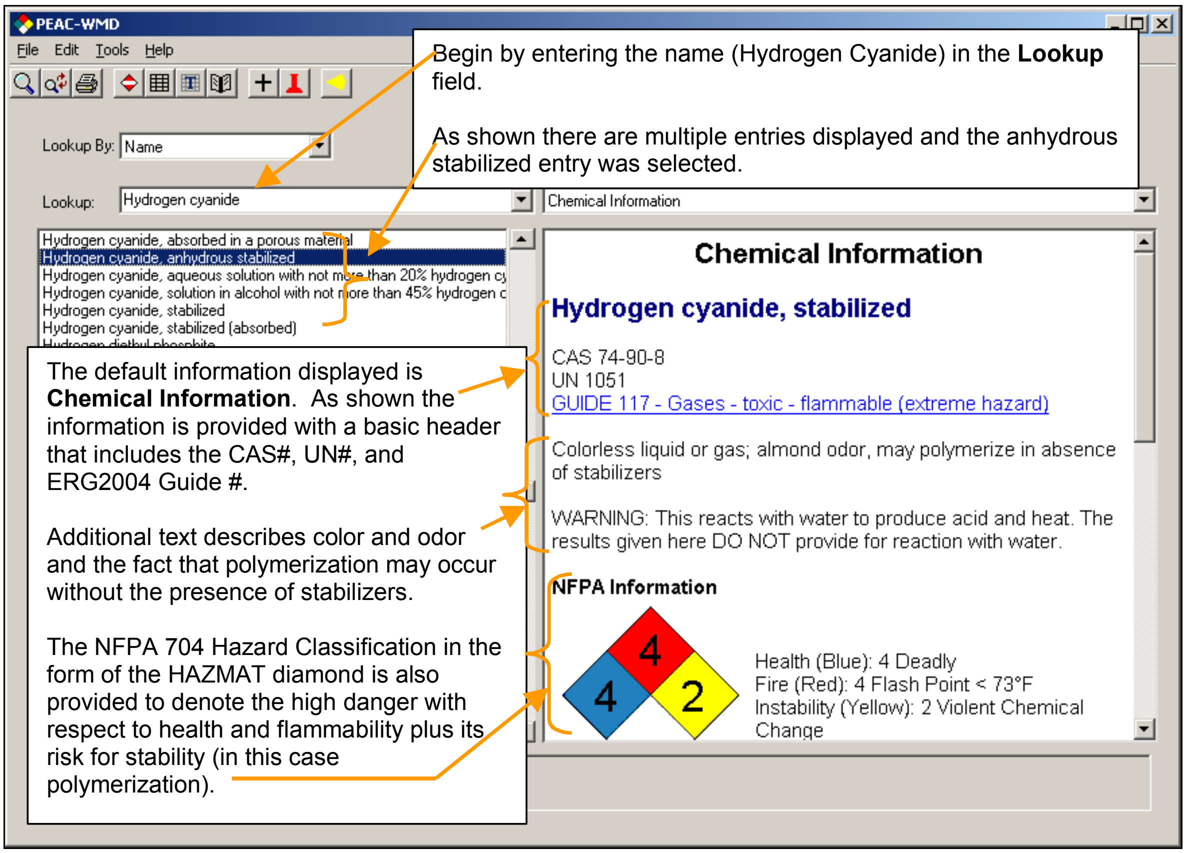


Figure 1 – Finding Hydrogen Cyanide in the PEAC-WMD database

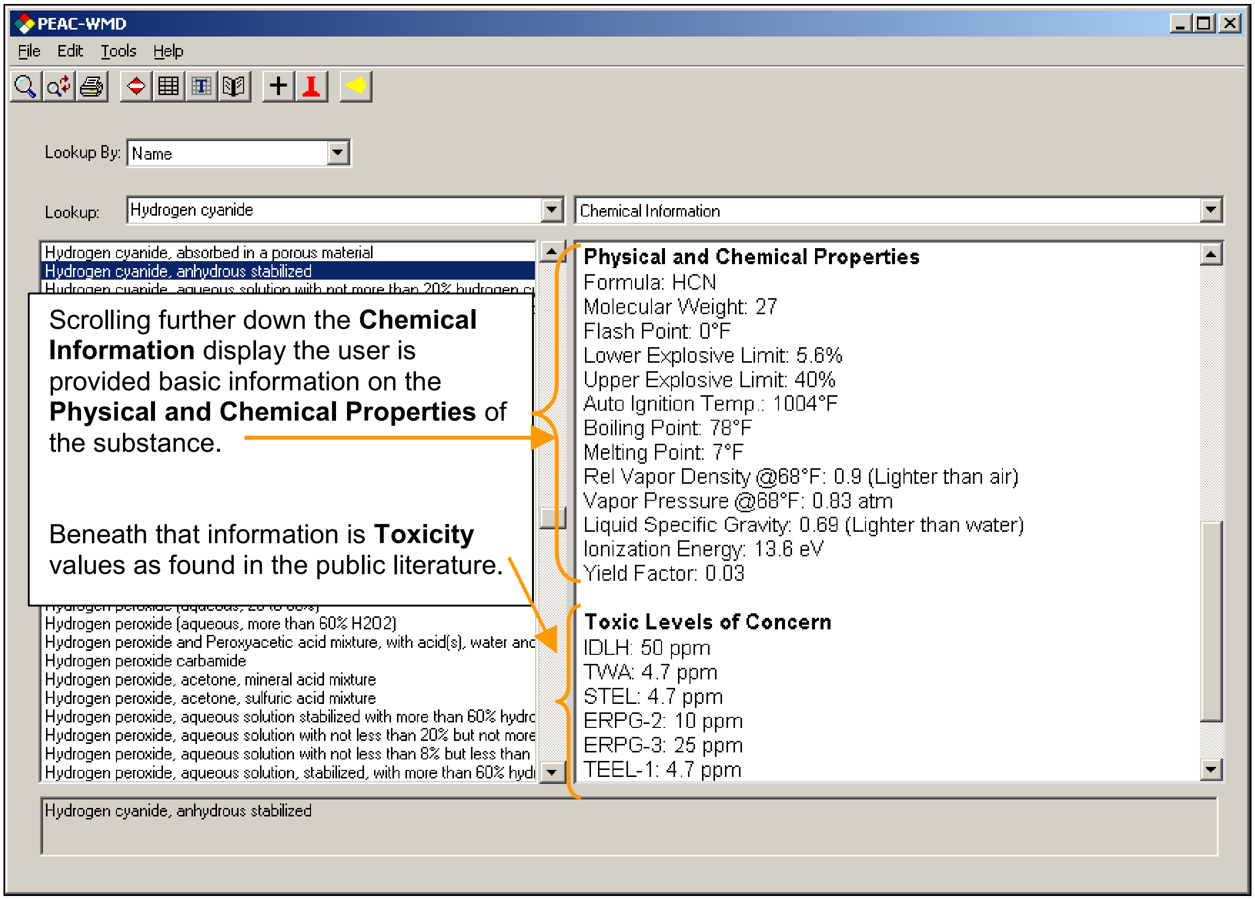


Figure 2 – Bottom portion of the Hydrogen Cyanide Chemical Information Display

Review of the information displayed in the chemical properties screen whether in Figure 1 and 2 (above) or Figures 3-7 (below), show chemical properties values discussed earlier in this discussion. As the reader can see, the published toxicity values, e.g., ERPGs (Emergency Response Planning Guidelines) published by the American Industrial Hygiene Association and the TEELs (Temporary Emergency Exposure Limits) published by Department of Energy are provided. We will use the ERPG-2 as the Level of Concern when we develop the Protective Action Distance (PAD) a little later.

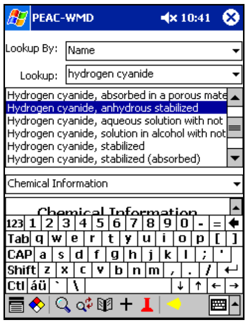


Figure 3- Selecting Hydrogen Cyanide using the PEAC-WMD for Pocket PC application

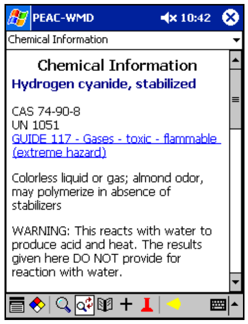


Figure 4 – Viewing the upper portion after toggling OFF the keyboard and toggling ON Full Screen

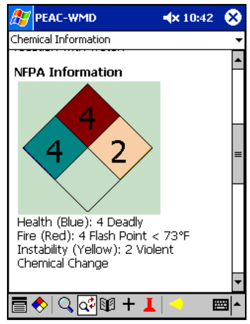


Figure 5 – The NFPA 704 Hazard Classification info

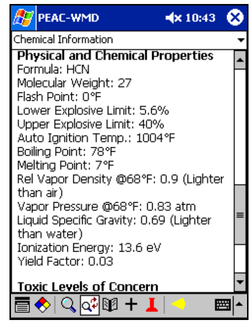


Figure 6 – The Chemical and Physical Properties

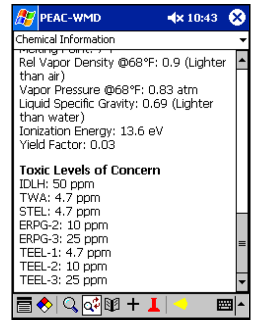


Figure 7 – The published Toxicity values

The PEAC-WMD application provides additional information and features the user can easily access by a simple click on the screen or selection from a screen menu. As an example, the user can toggle on the automatic Glossary feature by clicking on the Glossary icon [] that appears at the top of the screen in the Windows version of the application. With the Glossary toggle ON, those terms that appear in the Glossary portion of the PEAC-WMD application will appear in a different colored font on the display as a hyperlink. If the cursor is clicked on the term, a screen will appear that displays the definition of that term. In the example shown in Figure 8, the Glossary icon is toggled ON and the term “ERPG-2” was clicked on. The definition as displayed in the PEAC-WMD Glossary is shown in a separate window. Clicking on the [OK] button on the definition window will remove the definition.

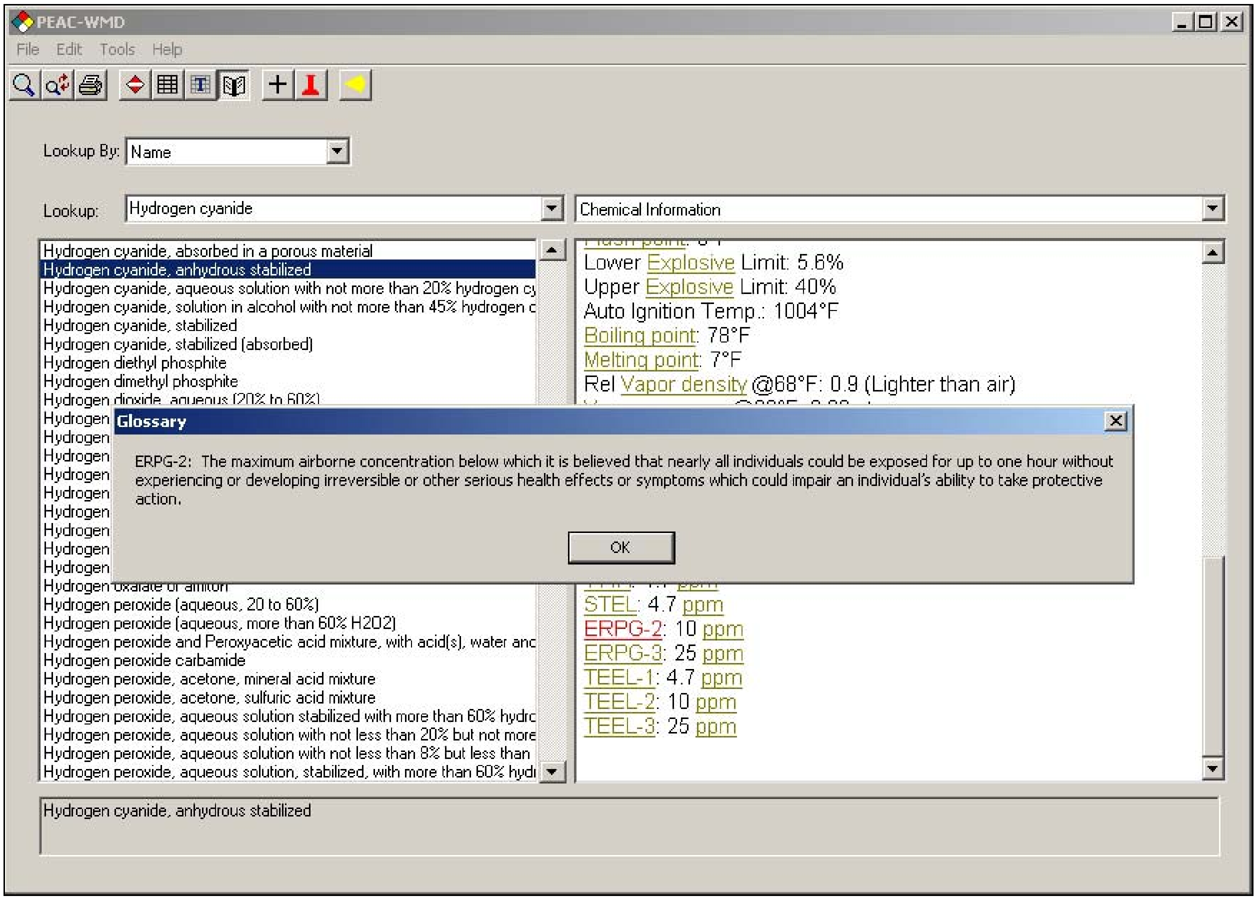


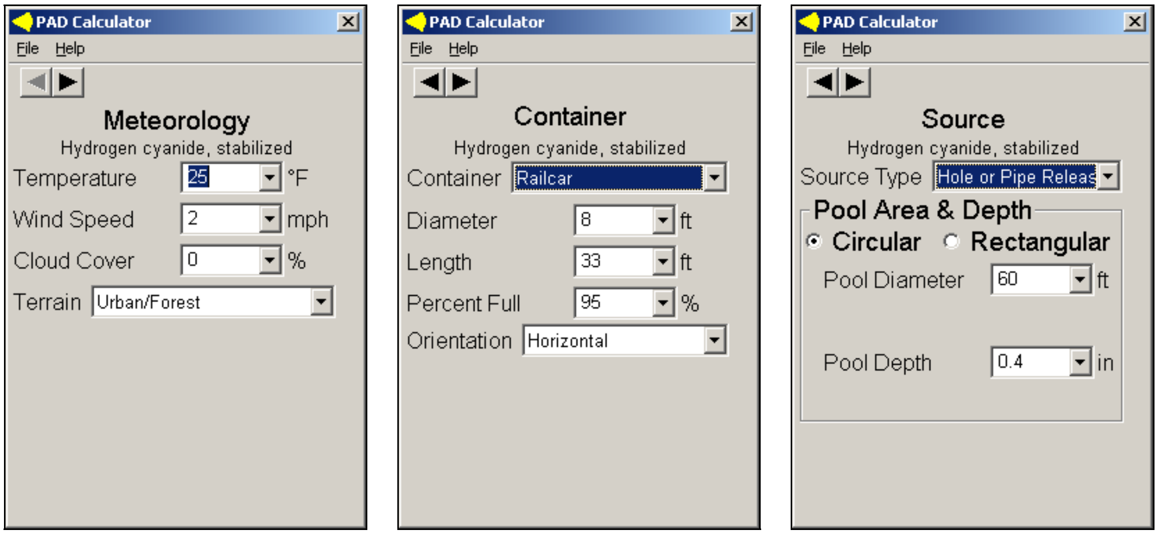
Figure 8 – Using the interactive Glossary feature

Another benefit of using the PEAC tool is assistance in the development of an evacuation zone for those chemicals that produce a toxic vapor cloud. As with most of our past 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 provides evacuation or exclusion zones.

For our hypothetical scenario using Hydrogen Cyanide as the involved chemical we'll set the location to be plastics manufacturing facility located outside Detroit, MI. The date is January 24, about 1:30 AM with a temperature of 25°F, wind speed of 2 mph and a clear sky. The hypothetical release involves a rail car that contains Hydrogen Cyanide and a transfer line has failed during off-loading operations and a pool (~60 foot diameter) of Hydrogen Cyanide has formed before the transfer line was isolated. The PEAC tool can provide guidance with regards to toxic vapor cloud that is released.

If you decide to follow along as we proceed through these examples, remember to set the location to Detroit and set the date and time to the proper values, otherwise you'll compute different values. We'll use a terrain type of urban/forest since this is a manufacturing facility and has buildings and processing equipment in the immediate area.

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 9. Following through the screens, we provide information on the Meteorology, Container Size, and Type of Release (Source). The following figures demonstrate how we would work through our scenario to see what our Protective Action Distance should be.



Meteorology
It's Detroit in January and the temperature about 25°, wind is set for 2 mph, clear skies and the terrain is **Urban/Forest** since it's a processing facility setting.

Container
We have selected from our list of container sizes the **Railcar** selection with a default 8' diameter and a 33' length. This gets us a quick estimate of how much material might be involved.

Source
We have selected a **Hole or Pipe Release**, and since the liquid boils at 78°F it will be released as a liquid and form a pool that was specified as 60' in diameter.

Figure 9 - Calculating a PAD using the PEAC-WMD System

By clicking the right arrow at the top of the screen, the PEAC system will calculate a PAD based on the default Level of Concern, which is the IDLH or 50 ppm. The PAD is calculated to be 1.1 miles in length as shown in Figure 10.

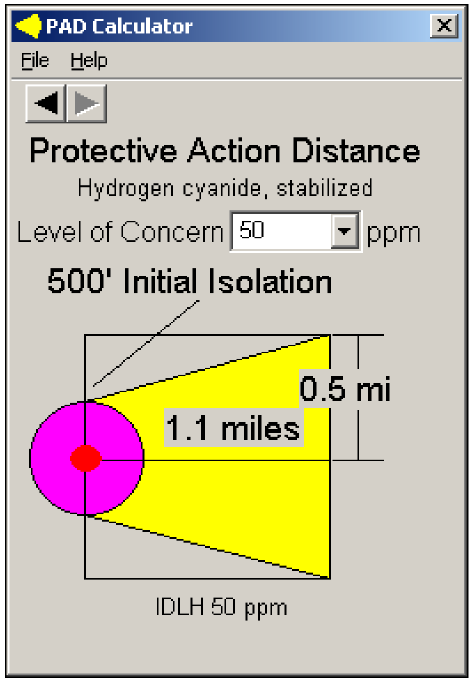


Figure 10 – PAD based on the IDLH of 50 ppm

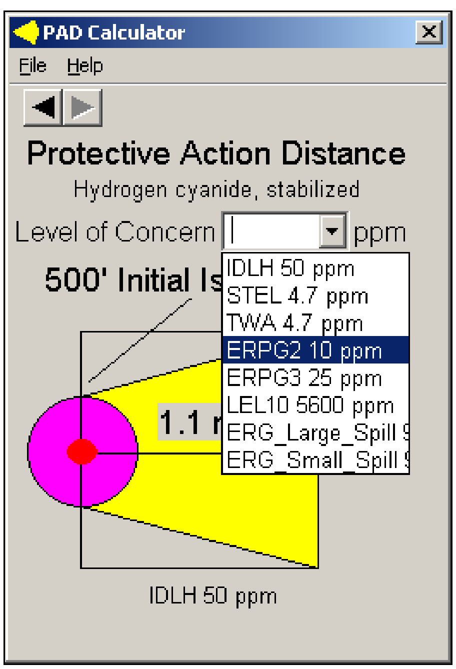


Figure 11 – Selecting another Level of Concern for the PAD

But perhaps we don't want to base the exclusion zone on the IDLH concentration; rather the decision is to use the ERPG-2 value as defined by the AIHA (American Industrial Hygiene Association). The definition of the ERPG-2 is "The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action."

A new PAD can be quickly computed by selecting the ERPG-2 value from the list of published toxicity values as shown in Figure 11.

Instantly the PEAC-WMD application provides a new PAD as shown in Figure 12.

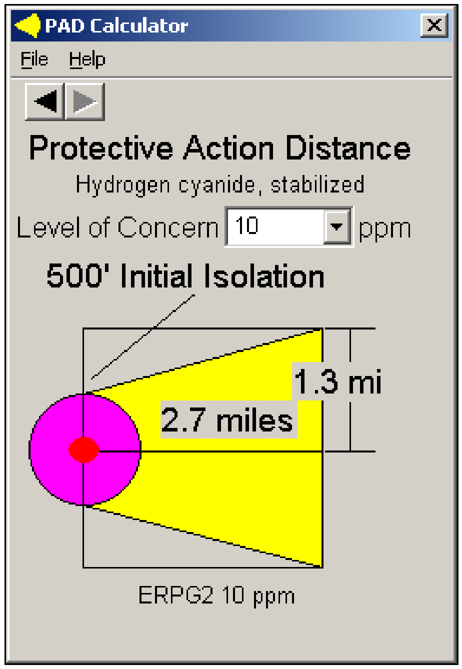


Figure 12 – The PAD based on the ERGP-2 Level of Concern

When the user exits the **PAD Calculator** by clicking on the [X] at the top right of the screen, a **PAD Results** report is generated and displayed in the Data Display Field of the PEAC-WMD application, Figure 13. The bottom of the report has the calculated PAD graphic displayed, Figure 14. This report can be copied or printed or recalled at a later time as needed for report development.

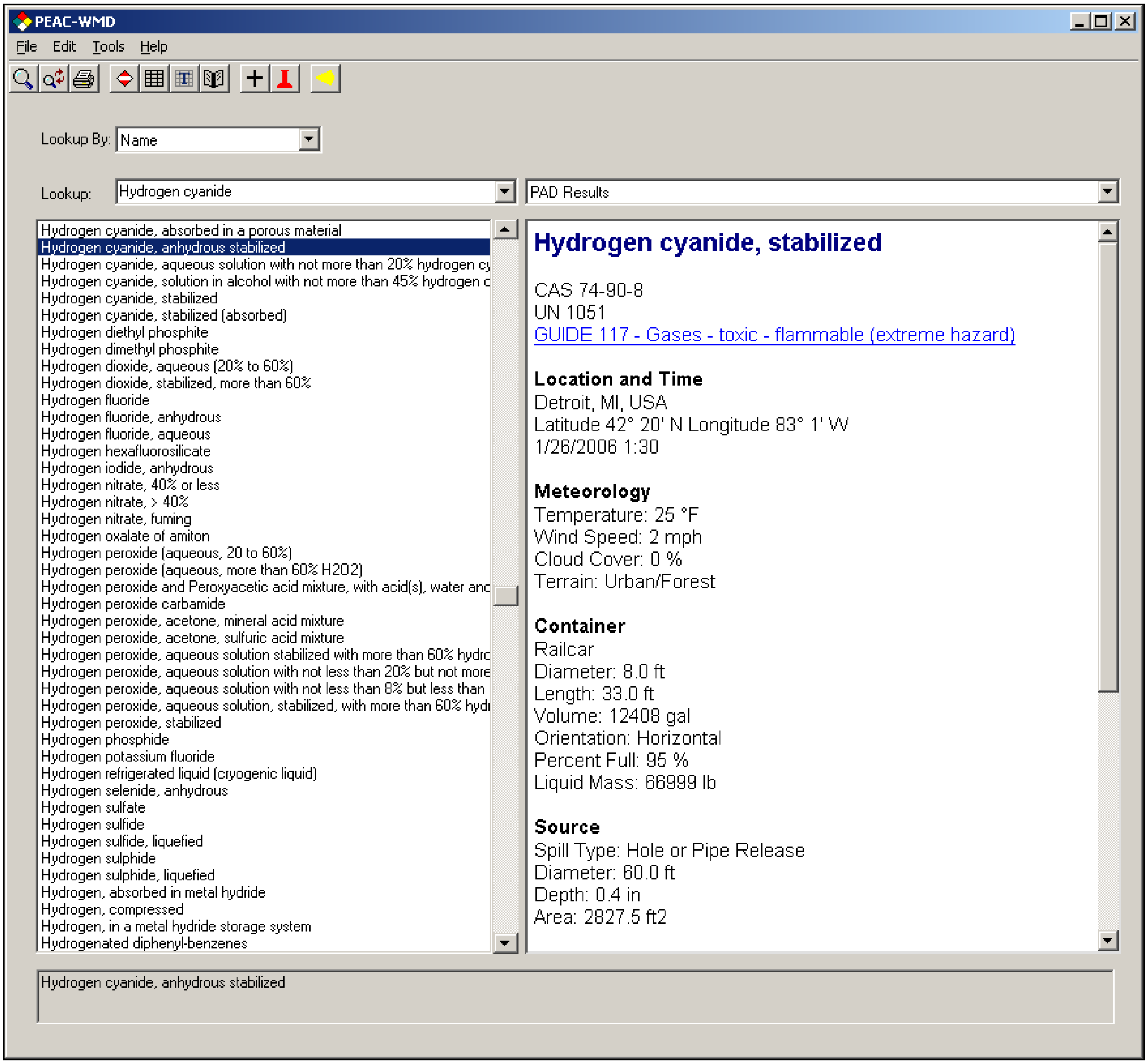


Figure 13 – PAD Results report generated when the PAD Calculator is exited

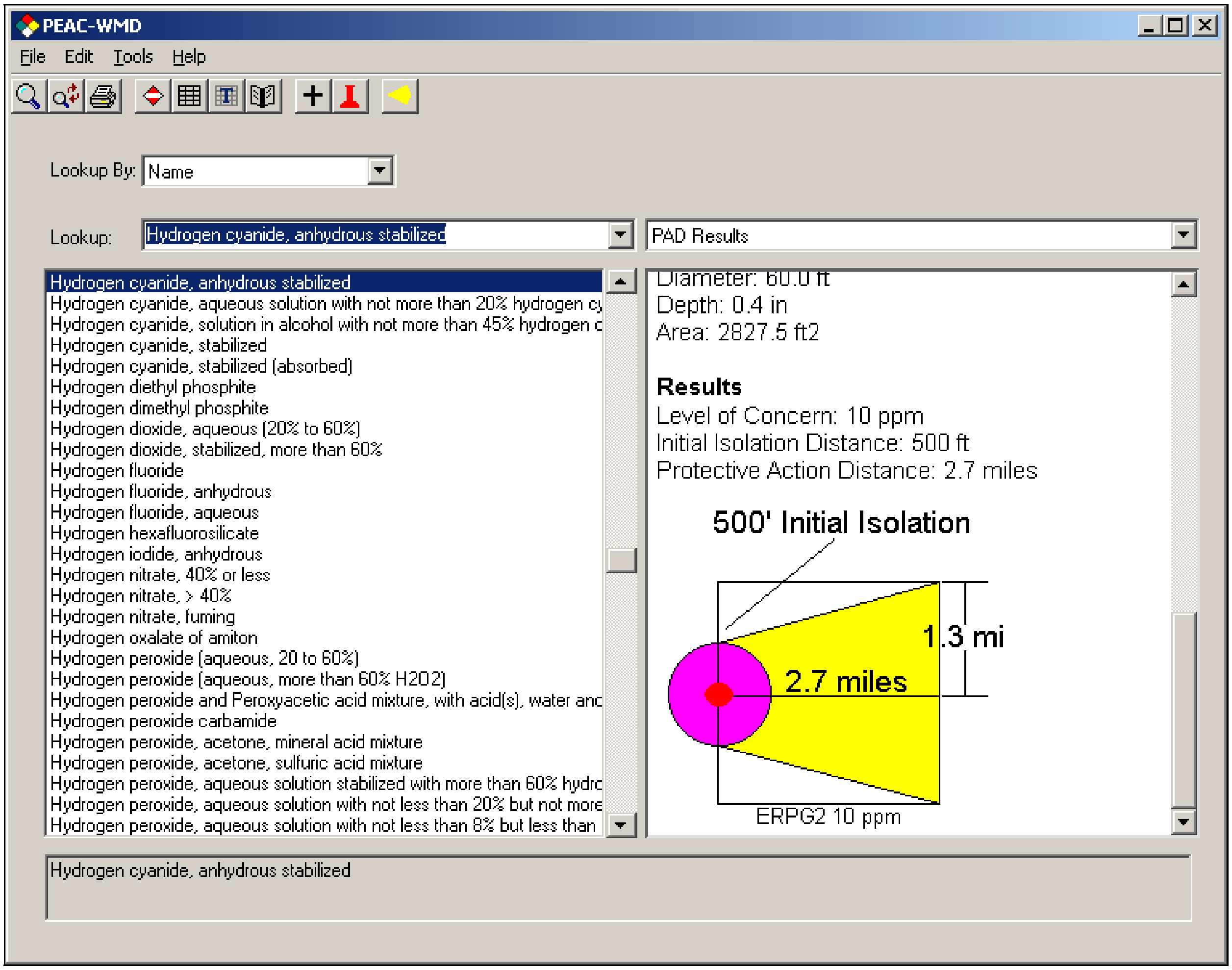


Figure 14 – The PAD graphic as displayed in the PAD Results report

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/.