Let's Take A PEEK at the PEAC software

PEAC Example–Formaldehyde

by S. Bruce King

This month our example is Formaldehyde, which has a chemical formula of H_2CO. Formaldehyde is listed under the UN # (United Nations Number) by the US Department of Transportation: UN 2209 (formalin) and has a CAS # of 50-00-0.

Persons exposed only to formaldehyde vapor do not pose substantial risks of secondary contamination. Persons whose clothing or skin is contaminated with a solution of formaldehyde in water or methanol can cause secondary contamination by direct contact or through off-gassing vapor. Formaldehyde is a colorless, highly toxic, and flammable gas at room temperature that is slightly heavier than air. It has a pungent, highly irritating odor that is detectable at low concentrations, but may not provide adequate warning of hazardous concentrations for sensitized persons. It is used most often in an aqueous solution stabilized with methanol (formalin). Most formaldehyde exposures occur by inhalation or by skin or eye contact. Formaldehyde is absorbed well by the lungs, gastrointestinal tract, and, to a lesser extent, skin.

Formaldehyde is a nearly colorless gas with a pungent, irritating odor even at very low concentrations (below 1 ppm). Its vapors are flammable and explosive. Because the pure gas tends to polymerize, it is commonly used and stored in solution. Formalin, the aqueous solution of formaldehyde (30% to 50% formaldehyde), typically contains up to 15% methanol as a stabilizer.

Most formaldehyde exposures occur by inhalation or by skin/eye contact. Formaldehyde vapor is readily absorbed from the lungs. In cases of acute exposure, formaldehyde will most likely be detected by odor; however, persons who are sensitized to formaldehyde may experience headaches and minor eye and airway irritation at levels below the odor threshold (odor threshold is 0.5 to 1.0 ppm; OSHA PEL is 0.75 ppm). **For sensitized persons, odor is not an adequate indicator of formaldehyde's presence and may not provide reliable warning of hazardous concentrations. Odor adaptation can occur.** Low-dose acute exposure can result in headache, rhinitis, and dyspnea; higher doses may cause severe mucous membrane irritation, burning, and lacrimation, and lower respiratory effects such as bronchitis, pulmonary edema, or pneumonia. Sensitive individuals may experience asthma and dermatitis, even at very low doses. Formaldehyde vapors are slightly heavier than air and can result in asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children exposed to the same levels of formaldehyde as adults may receive larger doses because they have greater lung surface area:body weight ratios and increased minute volumes:weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of formaldehyde found nearer to the ground.

Ocular exposure to formaldehyde vapors produces irritation and lacrimation. Depending on the concentration, formaldehyde solutions may cause transient discomfort and irritation or more severe effects, including corneal opacification and loss of vision. Formaldehyde is absorbed through intact skin and may cause irritation or allergic dermatitis; rapid metabolism makes systemic effects unlikely following dermal exposure.

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

Ingestion of as little as 30 mL (1 oz.) of a solution containing 37% formaldehyde has been reported to cause death in an adult. Ingestion may cause corrosive injury to the gastrointestinal mucosa, with nausea, vomiting, pain, bleeding, and perforation. Corrosive injuries are usually most pronounced in the pharyngeal mucosa, epiglottis and esophagus. Systemic effects include metabolic acidosis, CNS depression and coma, respiratory distress, and renal failure.

Sources/Uses Formaldehyde is synthesized by the oxidation of methanol. It is among the 25 most abundantly produced chemicals in the world and is used in the manufacture of plastics, resins, and urea-formaldehyde foam insulation. Formaldehyde or formaldehyde containing resins are used in the manufacture of chelating agents, a wide variety of organic products, glass mirrors, explosives, artificial silk, and dyes. It has been used as a disinfectant, germicide, and in embalming fluid. In the agricultural industry, formaldehyde has been used as a fumigant, preventative for mildew in wheat and rot in oats, a germicide and fungicide for plants, an insecticide, and in the manufacture of slow-release fertilizers. Formaldehyde is found in construction materials such as plywood adhesives. Formaldehyde also is or has been used in the sugar, rubber, food, petroleum, pharmaceuticals, and textiles industries.

Physical Properties

Description: Nearly colorless gas with a pungent, irritating odor.

Warning properties: Odor is detectable at less than 1 ppm, but many sensitive persons experience symptoms below the odor threshold.

Molecular weight: 30.0 daltons

Melting Point: -134°F(-92°C)

Boiling point: (760 mm Hg): - 6°F (-21°C)

Vapor pressure: 3883 mm Hg at 77°F (25°C)

Gas density: 1.07 (air = 1)

Water solubility: 55% at 68°F (20°C)

Flammability: Flammable gas between 7% and 73% at 77°F (25°C) (concentration in air); combustible liquid (formalin).

Synonyms include Methanal, Methyl Aldehyde, and Methylene Oxide.

Standards and Guidelines OSHA PEL (permissible exposure limit) = 0.75 ppm (averaged over an 8-hour workshift)

OSHA STEL (short-term exposure limit) = 2 ppm (15 minute exposure)

NIOSH IDLH (immediately dangerous to life or health) = 20 ppm

AIHA ERPG-2 (emergency response planning guideline) (the 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

Incompatibilities Formaldehyde reacts with strong oxidizers, alkalis, acids, phenols, and urea. Pure formaldehyde has a tendency to polymerize.

The systemic effects of formaldehyde are due primarily to its metabolic conversion to formate, and may include metabolic acidosis, circulatory shock, respiratory insufficiency, and acute renal failure.

Formaldehyde is a potent sensitizer and a probable human carcinogen.

Acute Exposure Formaldehyde vapor produces immediate local irritation in mucous membranes, including eyes, nose, and upper respiratory tract. Ingestion of formalin causes severe injury to the gastrointestinal tract. The exact mechanism of action of formaldehyde toxicity is not clear, but it is known that it can interact with molecules on cell membranes and in body tissues and fluids (e.g., proteins and DNA) and disrupt cellular functions. High concentrations cause precipitation of proteins, which results in cell death. Absorption from the respiratory tract is very rapid; absorption from the gastrointestinal tract is also rapid, but may be delayed by ingestion with food. Once absorbed, formaldehyde is metabolized to formic acid, which may cause acid-base imbalance and a number of other systemic effects.

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

CNS Malaise, headache, sleeping disturbances, irritability, and impairment of dexterity, memory, and equilibrium may result from a single, high level, exposure to formaldehyde.

Respiratory Even fairly low concentrations of formaldehyde can produce rapid onset of nose and throat irritation, causing cough, chest pain, shortness of breath, and wheezing. Higher exposures can cause significant inflammation of the lower respiratory tract, resulting in swelling of the throat, inflammation of the windpipe and bronchi, narrowing of the bronchi, inflammation of the lungs, and accumulation of fluid in the lungs. Pulmonary injury may continue to worsen for 12 hours or more after exposure. Previously sensitized individuals can develop severe narrowing of the bronchi at very low concentrations (e.g., 0.3 ppm). Bronchial narrowing may begin immediately or can be delayed for 3 to 4 hours; effects may worsen for up to 20 hours after exposure and can persist for several days.

Exposure to certain chemical irritants 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 may be more vulnerable

because of relatively increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic Accumulation of formic acid can cause an anion-gap acid-base imbalance. If formalin is ingested, absorption of the methanol stabilizer may contribute to the imbalance and can result in an osmolal gap, as well as an anion gap.

Immunologic In persons who have been previously sensitized, inhalation and skin contact may cause various skin disorders, asthma-like symptoms, anaphylactic reactions and, rarely, hemolysis. The immune system in children continues to develop after birth, and thus, children may be more susceptible to certain chemicals.

Gastrointestinal Ingestion of aqueous solutions of formaldehyde can result in severe corrosive injury to the esophagus and stomach. Nausea, vomiting, diarrhea, abdominal pain, inflammation of the stomach, and ulceration and perforation of the oropharynx, epiglottis, esophagus, and stomach may occur. Both formaldehyde and the methanol stabilizer are easily absorbed and can contribute to systemic toxicity.

Ocular Exposure to low concentrations of formaldehyde vapor can cause eye irritation, which abates within minutes after exposure has ended. Formalin splashed in the eyes can result in corneal ulceration or cloudiness of the eye surface, death of eye surface cells, perforation, and permanent loss of vision; these effects may be delayed for 12 hours or more.

Dermal Exposure to formaldehyde vapor or to formalin solutions can cause skin irritation and burns. In sensitized persons, contact dermatitis may develop at very low exposure levels.

Potential Sequelae In survivors of inhalation injury, pulmonary function usually returns to normal. Eye exposure to high concentrations of formaldehyde vapor or formalin can eventually cause blindness. Narrowing of the esophagus and severe corrosive damage to the stomach lining can result from ingesting formalin.

Chronic Exposure The major concerns of repeated formaldehyde exposure are sensitization and cancer. In sensitized persons, formaldehyde can cause asthma and contact dermatitis. In persons who are not sensitized, prolonged inhalation of formaldehyde at low levels is unlikely to result in chronic pulmonary injury. Adverse effects on the central nervous system such as increased prevalence of headache, depression, mood changes, insomnia, irritability, attention deficit, and impairment of dexterity, memory, and equilibrium have been reported to result from long-term exposure. Chronic exposure may be more serious for children because of their potential longer latency period.

Carcinogenicity The Department of Health and Human Services has determined that formaldehyde may reasonably be anticipated to be a carcinogen. In humans, formaldehyde exposure has been weakly associated with increased risk of nasal cancer and nasal tumors were observed in rats chronically inhaling formaldehyde.

Reproductive and Developmental Effects There is limited evidence that formaldehyde causes adverse reproductive effects. The TERIS database states that the risk of developmental defects to the exposed fetus ranges from none to minimal.

Formaldehyde is not included in *Reproductive and Developmental Toxicants*, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals widely acknowledged to have reproductive and developmental consequences.

There have been reports of menstrual disorders in women occupationally exposed to formaldehyde, but they are controversial. Studies in experimental animals have reported some effects on spermatogenesis. Formaldehyde has not been proven to be teratogenic in animals and is probably not a human teratogen at occupationally permissible levels. Formaldehyde has been shown to have genotoxic properties in human and laboratory animal studies producing sister chromatid exchange and chromosomal aberrations.

Special consideration regarding the exposure of pregnant women is warranted, since formaldehyde has been shown to be a genotoxin; thus, medical counseling is recommended for the acutely exposed pregnant woman.<

In using the PEAC application we access information for the chemical by first locating Formaldehyde 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.

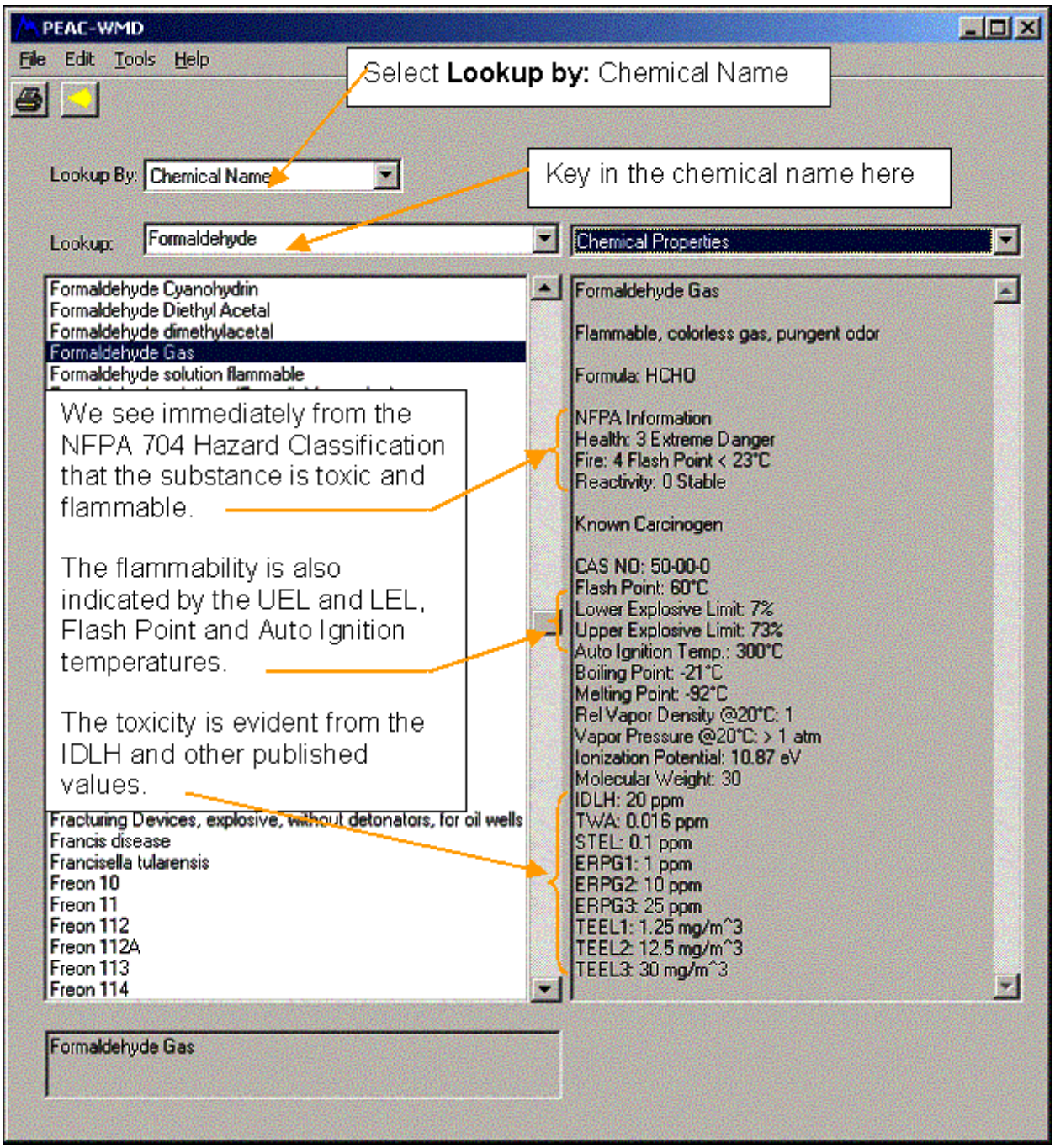


Figure 1 - Using the Lookup By: Name for Formaldehyde using the PEAC-WMD for Windows application

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 below, the published toxicity values, e.g., IDLH, ERPGs, 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.

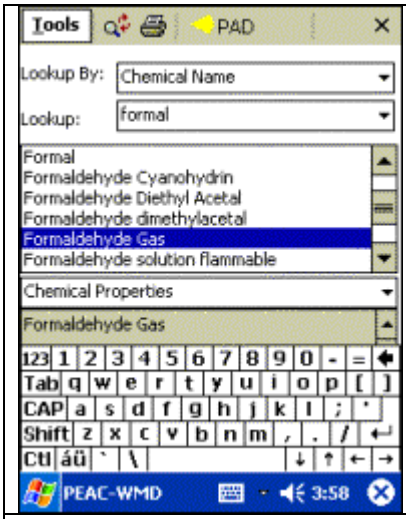


Figure 2 – Selecting Formaldehyde using the PEAC-WMD for Pocket PC application

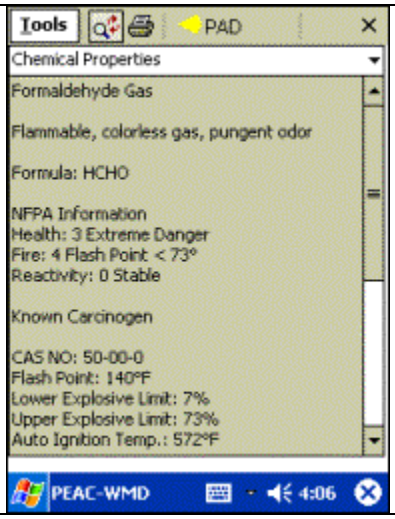


Figure 3 – The top portion of the Chemical Properties Data Display Screen

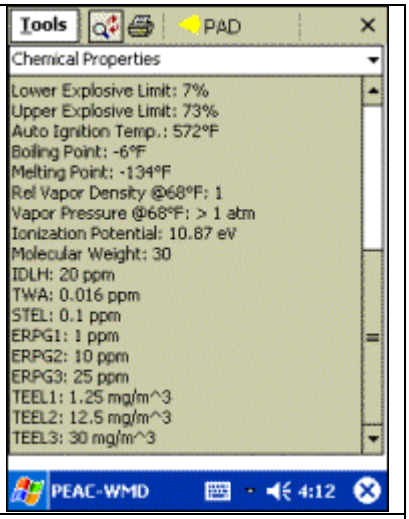


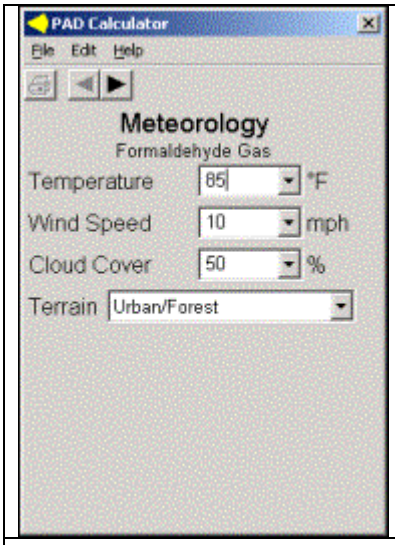
Figure 4– The bottom portion of the Chemical Properties Data Display Screen

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. If transported as a compressed liquefied vapor it 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 Formaldehyde as the involved chemical we'll set the location to be an urea-formaldehyde foam insulation facility located in Miami, FL. The date is October 13, 2003, about 12:30 PM with a temperature of 85°F, a wind speed of 10 mph with a partly cloudy sky for the daytime release. The release involves a portable tank that has a 1" transfer valve knocked off by a forklift. The PEAC tool can provide guidance with regards to toxic vapor cloud that is released.

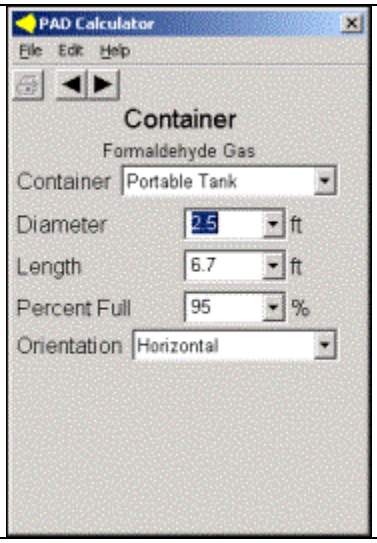
If you decide to follow along as we proceed through these examples, remember to set the location to Miami and set the date and time to the proper values, otherwise you'll compute different values. Also it should be understood that the examples shown below assume that no explosion or fire is involved, otherwise the Formaldehyde would ignite.

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 5. 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 Miami in October and the temperature about 85°, wind is set for 10 mph, partly cloudy skies and the terrain is **Urban/Forest** since it's an industrial setting.



Container

We have selected from our list of container sizes the **Portable Tank** selection; this gives some quick dimensions that should get us close to the right size.

Source

We have selected a **Hole or Pipe Release** for the type of release with a **1" Hole Diameter**.

Figure 5 – Calculating a PAD using the PEAC-WMD System for October 13th

By pressing the right arrow at the top of the screen, the PEAC system will display a screen as shown in Figure 6. This calculates a **PAD** (Protective Action Distance) based on the default **Level of Concern** the IDLH of 20 ppm. This evacuation or standoff distance is based on the toxicity of Formaldehyde.

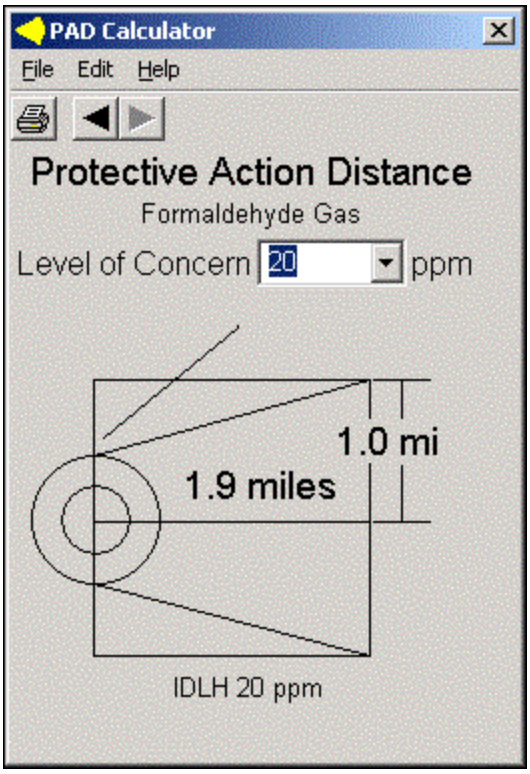


Figure 6 – Default PAD for Formaldehyde using the IDLH of 20 ppm

If we felt that the IDLH was not a conservative enough concentration to provide adequate protection to the public, we can quickly compute another PAD using another Level of Concern concentration. For instance, we could select the ERPG-2 value from the pop-up list as shown in Figure 7. The results of the new calculations are shown in Figure 8.

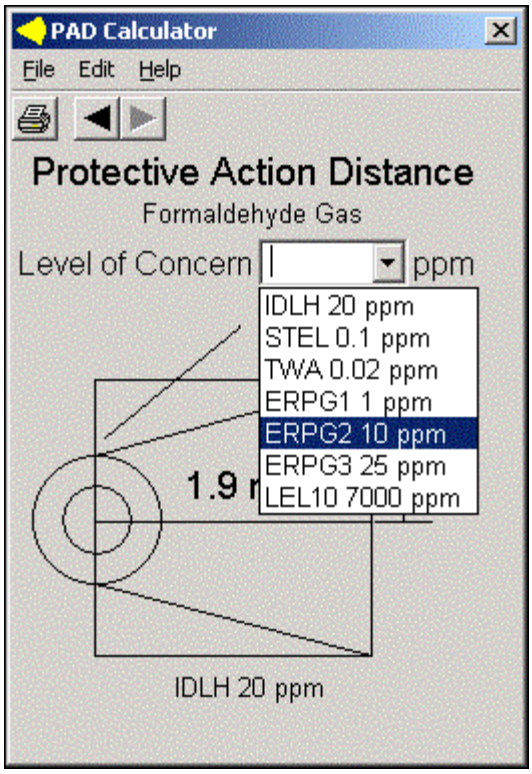


Figure 7 – Selecting another Level of Concern from the pop-up list

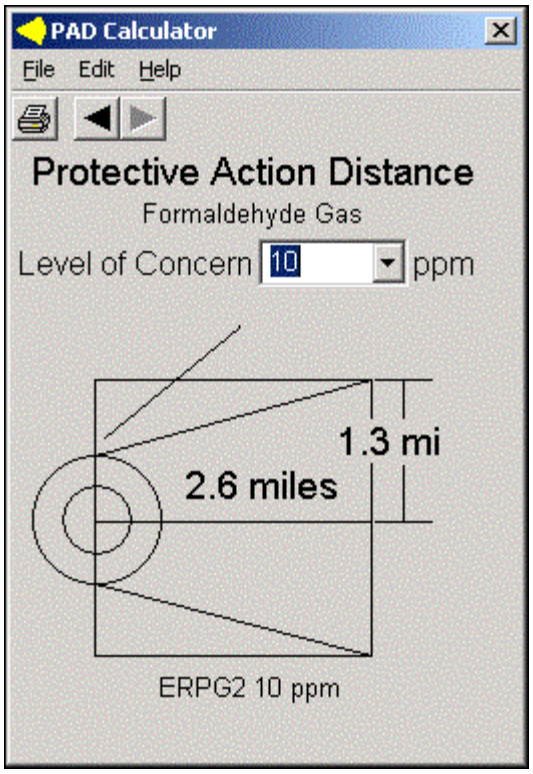


Figure 8 – The PAD calculated based on the ERPG-2 LOC of 10 ppm.

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/.