FESTUS MISSOURI 2002 CHLORINE RELEASE ACCIDENT

We will look a real-world example of a hazardous chemical release and model it using the PEAC tool.

Chlorine Release at Festus, Missouri, 14 August 2002
(information from U.S. Chemical Safety and Hazard Investigation Board (CSB) report # 202-04-I-MO released May 2003)

Google Earth image of site. Chlorine spill took place at + in center at 38.1807 N Latitude, 90.3915 W Longitude. DPC Enterprises in center, Goodwin Brothers Construction on other side of U.S. Hwy 61 at upper right, Almony Farm at upper left., Blue Fountain Trailer Park just outside photo at bottom.

The DPC Enterprises facility at Festus, Missouri, is in the business of receiving liquefied chlorine from 90-ton railcars and repackaging it into 150-pound and 1-ton containers for commercial, industrial, and municipal use in the St. Louis metropolitan area. The chlorine transfer operations take place during one shift, typically from 6 AM through 4 PM Monday through Friday. The facility employs 12 people. The DPC facility has three chlorine tank car unloading stations, but only one station is used at a time. Each unloading station is equipped with three chlorine transfer hoses, each 1-inch in diameter and 11 feet long.

On 14 August 2002, during routine chlorine transfer operations which had started at 6:30 AM, one of the 1-inch chlorine transfer hoses failed releasing chlorine. Furthermore, the automatic shutoff valves designed to shutoff the chlorine also failed to activate. According to employee interviews conducted later by the U.S. Chemical Safety Board (CSB), the three employees outside heard a loud pop at approximately 9:20 AM and observed a continuous release form chlorine at tank car station #3 (marked + on the photo). The three employees evacuated. The leak activated an area chlorine detection monitor audio alarm. The inside employees exited the building. The operations manager as he exited tried to manually shutdown the packaging system by pressing an ESD button, but nothing happened. The system is designed to automatically shutdown based on chlorine detection levels, and although both manual and automatic shutdown systems were activated they failed to activate. Furthermore, although the facility had four self-contained breathing apparatus (SCBA) units and employees were trained on its use, the men were unable to gather the equipment as they left the building because the equipment was too close to the spill site. The employees drove away from the area using U.S. Hwy 61 both north and south; there was no community-wide alert systems in place to warn of the chlorine spill.

The owners of nearby Goodwin Brothers and an employee at adjacent Intermodal Tire (see area photo) on the other side of Hwy 61 saw the chlorine cloud approaching and warned their employees to escape. By the time all of the employees were notified, the chlorine cloud drifted across the highway moving slowly east-to-southeast. The wind speed was estimated at "calm" or sometimes 3 to 5 mph. Several employees drove through the chlorine cloud as they escaped and had to seek medical attention. The chlorine cloud tended to hug the ground and was only a few feet high.

At 9:27 AM, the DPC facility manager dialed 9-1-1 to report the chlorine release. The Jefferson County R-7 volunteer fire department within ten minutes. The R-7 fire chief requested 9-1-1 dispatch to notify mutual aid response fire departments and the Jefferson County HAZMAT unit. Emergency Response Personnel notified the Jefferson Memorial Assisted Living Facility and the St. Pius High School to shelter in place. A drive-through "bull horn" notification, followed by door-to-door evacuation was conducted at the Blue Fountain mobile home park and the Howe Crossing residential area. It took personnel over one hour to evacuate these areas. Hwy 61was shut down as well as nearby Interstate 55. The accident caused 63 people from the surrounding community to seek medical evaluations for respiratory distress, with three people admitted for overnight observation.

The chlorine leak was stopped three hours after the transfer line break when emergency responders in protective gear "waded" through the four-foot high plume cloud and manually shut off several valves at the top of the rail tank. By that time, an estimated 48,000 lbs of chlorine had escaped over three hours time. The shelter-in-place order lasted four hours. At 5 PM, Hwy 61 was opened.

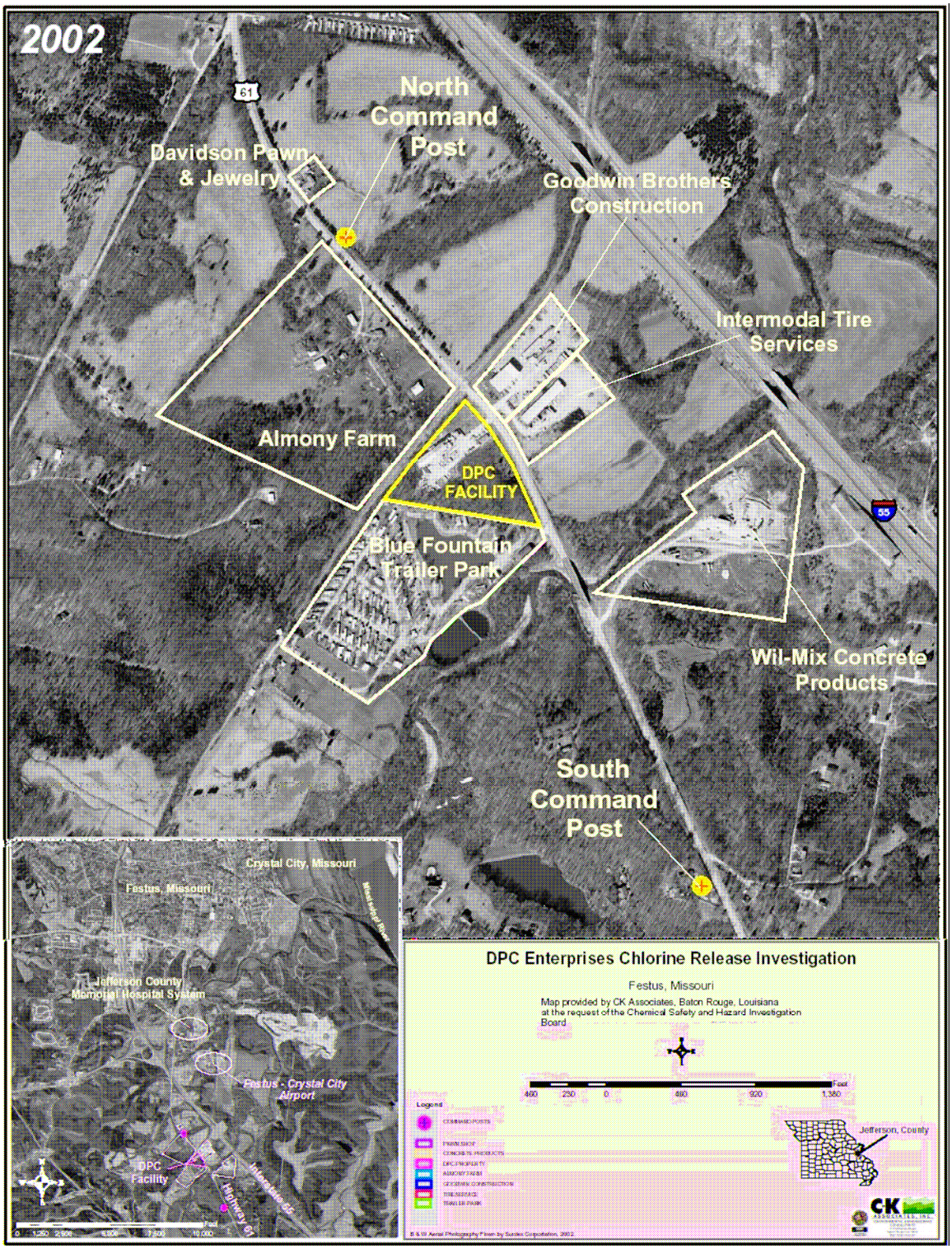
Some of the chlorine which had released from the failed transfer hose reacted with the air humidity to form chlorine hydrate, a solid material. The area was covered with several

feet of the hydrate material. Three DPC personnel wearing chlorine-resistant suits and carrying escape respirators placed lime or calcium carbonate on top of the chlorine hydrate. All three were injured in this operation and received medical attention. An environmental remediation company was called in and completed the cleanup.

The CSB determined that the cause of the transfer hose failure was that the transfer hose was made of stainless steel braiding which is easily corroded and weakened by chlorine. This type of transfer hose should have had an inner Teflon lining reinforced by an exterior metal braiding made of Hastelloy C-276, which is resistant to even moist chlorine. The two types of hoses look the same and are not distinguishable by color coding or other marking. CSB verified that DPC practice at Festus is to use only Hastelloy hose for chlorine transfer. CSB investigators found that shipping documents from the supplier indicated that the hose was of Hastelloy but the hose that failed was actually constructed of stainless steel. CBS testing of the three hoses found that two were of stainless steel and one was Hastelloy even though the shipping documents indicated that all three hoses were Hastelloy.

The automatic valve shutoff failure was due to valve corrosion from moisture, and DPC had failed to perform routine testing of the ESD valves to verify that they close on demand according to the CSB investigation. There was evidence of corrosion within the pad air supply and tank car unloading assemblies and within the facility piping. The corrosion products migrated to the valves and built up around the valves that prevented them from closing properly.

The CSB report stated that community notification systems were inadequate, both on the part of DPC notifying authorities and neighboring businesses and emergency personnel notifying the public. An adequate system should include the use of siren systems, automatic telephone alert systems, and radio and TV media. Local authorities must be involved in developing community notification systems. The Jefferson County Emergency Response Plan dated 1996 was too general and did not contain specific procedures for high public HAZMAT events such as a large chlorine release. Community sirens or alert networks that immediately notify the exposed public should be in place with radio and television to provide followup. There was too much time wasted when emergency response personnel drove through neighborhoods and went door-to-door to notify people to evacuate, which extended the period of public exposure. Other deficiencies were (1) delays caused the need to get permission for volunteer HAZMAT personnel to leave their regular jobs to respond to the incident and (2) response delays in traffic because the HAZMAT duty officer was not authorized to place markings or lights or sirens on his personal vehicle when responding to an emergency. There were also two command posts set up north and south of the site on Hwy 61, which resulted in some miscommunication incidents.



Aerial view of DPC Festus Facility and Surroundings from CSB report.

The following photos from CSB releases using TV footage show the chlorine cloud "hugging" the ground displaying dense gas behavior: The ruptured chlorine transfer hose is also shown.

Fox 2 News photo used in a CSB document showing chlorine cloud hugging ground, and three emergency responders in red suits wading through cloud and turning off valves at top of rail car

KTVI-TV, St. Louis, MO photo in final CSB report showing chlorine cloud hugging the ground and moving off site, note some upwind and downwind movement of cloud

CSB Report: Normal chlorine transfer operations at site showing three 1" diameter transfer hoses

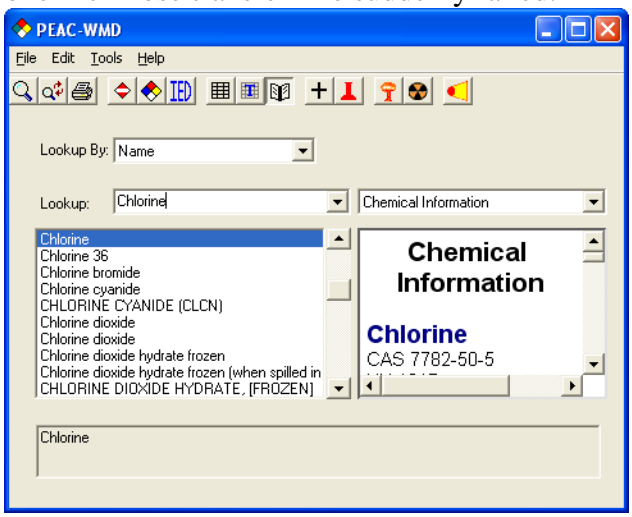
CSB report: ruptured transfer hose

In a May 2003 report, Trinity Consultants reported the results of the Festus chlorine release to CSB. They took the 48,000 lbs estimated chlorine release over a three hour period and used an average release rate of 4.44 lbs/sec. Mention of this is made of the modeling in the CSB report. They calculated a distance of 3.7 miles corresponding to a ground level, centerline concentration of 3 ppm. No details in the CSB report as to what model, wind speed, or cloud cover, or atmospheric stability was used by Trinity Consultants.

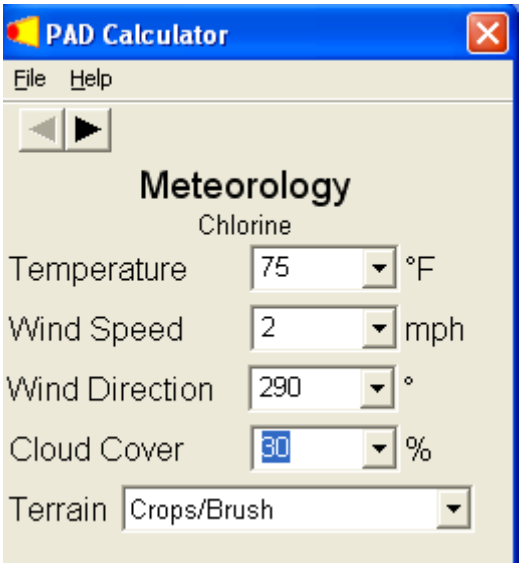
The 48,000 lbs estimated release is based on the difference in the weight of the tank car prior to the release and after the release. The rail car was 44.4% full (80,000 lbs) just before the release. There is an argument in the CSB report that DPC may have overestimated the amount of chlorine in the rail car at the time of the hose break, and the amount of chlorine released may have been in fact less than 48,000 lbs.

Modeling of the Festus Chlorine Release Using the PEAC Tool

The PEAC tool can be used for modeling the Festus chlorine release. The date (August 14) and time (9:30 AM) and coordinates (39.1807 N, 90.3915 W) should be entered. A GPS reading can be taken at some other location and an offset distance and direction specified to get the coordinates of the release site. Responders can also dispense with specifying coordinates all together and list a nearby city (e.g. St. Louis MO), but then they would not get an overlay of the Protective Action Distance (PAD) on a map. While modeling can be done using the PEAC tool specifying a chlorine release rate of 4.44 lbs/sec, in reality, emergency responders would not know this information at the time of the spill. This information was only made available after everything was over, and even then, there was some uncertainty. Most likely, DPC employees could only say that the one-inch hose transfer line suddenly failed.



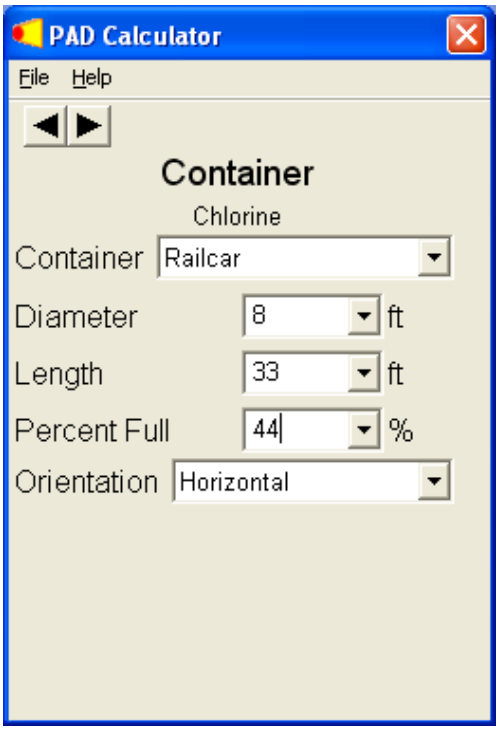
The user begins by selecting chlorine under "lookup". The user then selects the PAD icon,  .

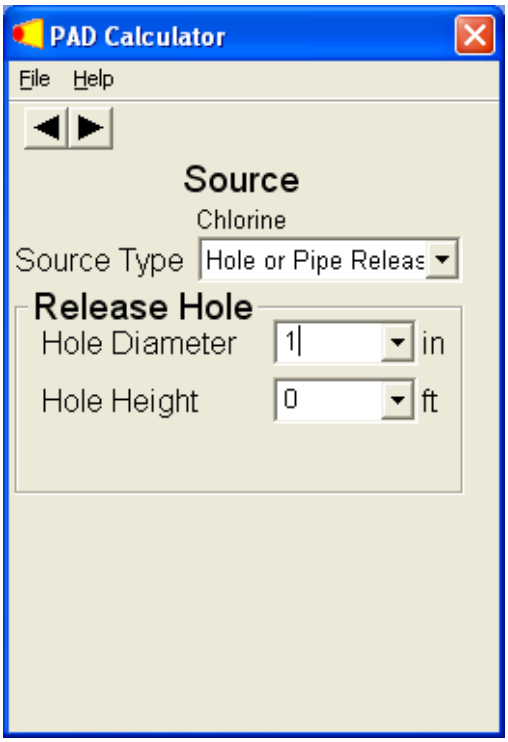


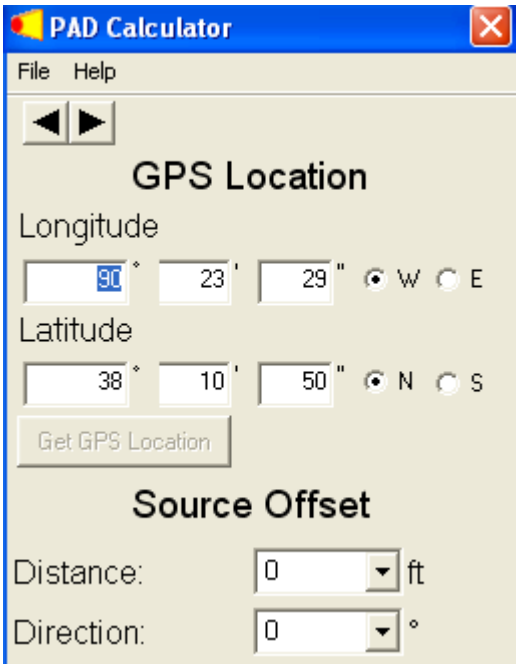
The user then enters basic information on meteorology and terrain. "Crops/Brush" includes light residential.

The user then selects "rail car" (the rail car size is immaterial, so we can use the default setting). A 1-inch hole or pipe most mimics the failed 1-inch transfer hose, so this is selected. The hose while it looks like from the photo that it is connected to the top of the tank is actually leaving at the tank bottom, so we will enter the "hole height" as "0".

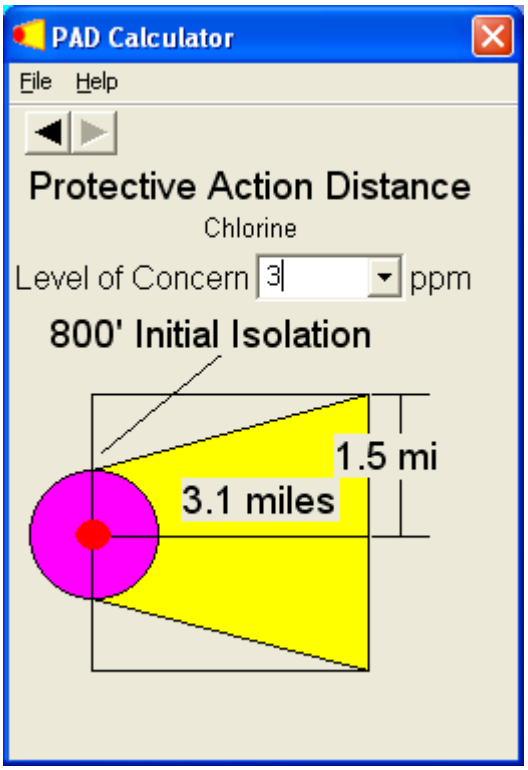
A PAD may be calculated based on a 3 ppm Level of Concern. Of course, the PEAC tool can be used to calculate a PAD for any level of concern.







Latitude and longitude can be entered as 38.1807 N and 90.3915 W, and the PEAC tool automatically calculates degrees, minutes, and seconds. We know the coordinates so there is no source offset.



The PAD is calculated at 3.1 miles. The 800' Initial Isolation came from the 2004 Emergency Response Guidebook

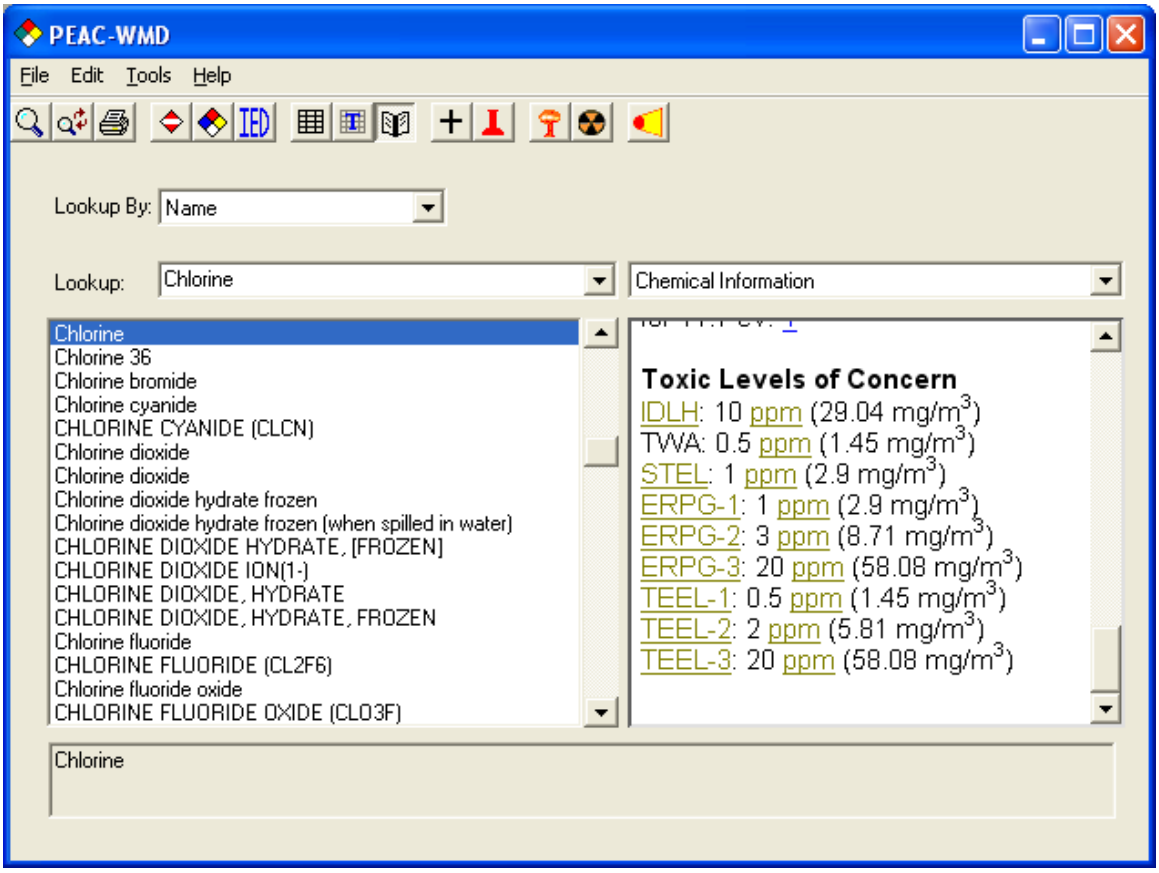
The Protection Action Distance for a given Level of Concern is strongly dependent upon atmospheric mixing because of solar heating of the ground. On a sunny day, the ground warms up, and the temperature of the air near the ground increases. Because warm air is less dense than cool air, the warm air near the surface rises and mixes with the cooler air higher in the sky. The effect is to break up and disperse the chlorine cloud. This is a good thing because PAD distances will be much less than if this thermal mixing did not occur. The air mass is said to be "unstable". The PEAC tool attempts to internally calculate the degree of chlorine cloud mixing and breakup based on the latitude, time of day, cloud cover, and wind speed. The ALOHA model which is used by the U.S. EPA does the same thing, in fact, the same mathematical relationships used in the ALOHA model are also used in the PEAC tool for determination of atmospheric stability. The model is very sensitive to solar heating. A very different PAD answer is obtained if the user inputs a 100% cloud cover instead of a 30% cloud cover. At a 100% cloud cover, the PAD is calculated to be 10.7 miles corresponding to a Level of Concern = 3 ppm. If there is no sunshine, the earth surface is not heated up, and there is no thermal mixing to disperse the chlorine cloud. At a 50% cloud cover, the PAD is calculated to be 5.5 miles. Between 0% and 30% cloud cover, the PAD is calculated to be 3.1 or 3.3 miles.

The percent cloud cover is not available in the CSB report, but available photographs at the site show shadows, and different accounts indicate a very low and variable wind speed and direction. There were reports of the chlorine cloud traveling southwest reaching the Blue Fountain Trailer Park, where the wind was "essentially calm". Probably what is happening was that the chlorine cloud was moving slowly in westward or southward or eastward directions and dispersed as it thinned out because of atmospheric mixing.

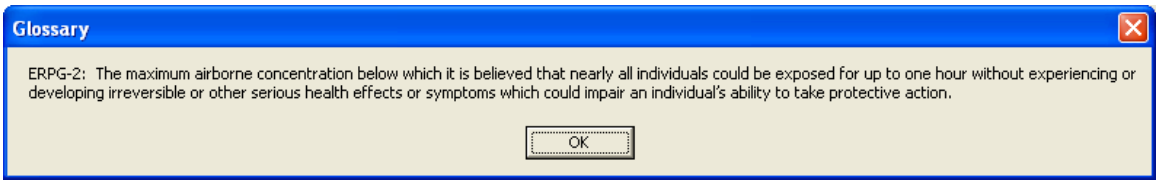
Remember that Trinity Consultants calculated 3.7 miles based on a Level of Concern of 3 ppm. chlorine. They used an average release rate of 4.44 lbs/sec based on the weight of the rail car before and after shutoff. The PEAC tool allows the user the option of using a release rate of 4.44 lbs/sec rather than specifying a one-inch hose break. The PAD calculated was somewhat less comparing the same wind speed and cloud cover. The PAD for a 4.44 lbs/sec varied between 1 and 3.7 miles at a 3 ppm Level of Concern depending upon the percent cloud cover and wind speed using the PEAC tool.

Level of Concern

The PEAC user can input almost any reasonable value for a "Level of Concern", and the PEAC tool will calculate a corresponding PAD. Various possible "Levels of Concern" and their meanings are listed under "Chemical Information" for chlorine. To access this list, the PEAC user may look under "Chemical Information", as illustrated below. The Levels of Concern are listed both in parts per million (ppm) and milligrams per cubic meter (mg/m^3). The lethal dose for chlorine by inhalation for 1-hour exposure is 300 ppm.



The meaning of the terms “IDLH”, “STEL”, “ERPG-1”, etc can be obtained by selecting the term and pulling up the definition on the screen. For example, if ERPG-2 is selected, the definition appears on the screen:



The U.S. Environmental Protection Agency favors the use of Acute Exposure Guideline Levels (AEGL) as Levels of Concern. These consider exposures at various concentrations for different lengths of time. They consider only acute effects and do not consider possible long term effects such as cancer or developing a sensitivity to the chemical. To access the AEGLs, the PEAC user selects “Acute Exposure Guideline Levels” instead of “Chemical Information” in the PEAC tool. The following information is then displayed:

Acute Exposure Guideline Levels

Chlorine

CAS 7782-50-5
UN 1017
GUIDE 124 - Gases - toxic and/or corrosive - oxidizing

Acute Exposure Guideline Levels (Status: Final)
Ten Minute AEGL-1: 0.5 ppm
Thirty Minute AEGL-1: 0.5 ppm
One Hour AEGL-1: 0.5 ppm
Four Hour AEGL-1: 0.5 ppm
Eight Hour AEGL-1: 0.5 ppm

Ten Minute AEGL-2: 2.8 ppm
Thirty Minute AEGL-2: 2.8 ppm
One Hour AEGL-2: 2 ppm
Four Hour AEGL-2: 1 ppm
Eight Hour AEGL-2: 0.71 ppm

Ten Minute AEGL-3: 50 ppm
Thirty Minute AEGL-3: 28 ppm
One Hour AEGL-3: 20 ppm
Four Hour AEGL-3: 10 ppm
Eight Hour AEGL-3: 7.1 ppm

Definitions

AEGL-1: The airborne Concentration of a substance at or above which it is predicted that the general population, including "susceptible" individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of Exposure.

AEGL-2: The airborne Concentration of a substance above which it is predicted that the general population, including "susceptible" individuals could experience irreversible or other serious, long-lasting health effects or impaired ability to escape.

AEGL-3: The airborne Concentration of a substance at or above which it is predicted that the general population including "susceptible" individuals could experience life-threatening health effects or death.

"Susceptible" individuals may include persons in the 40 to 65 age bracket, smokers, or people who use alcohol; but not hyper-susceptible or hypersensitive individuals.

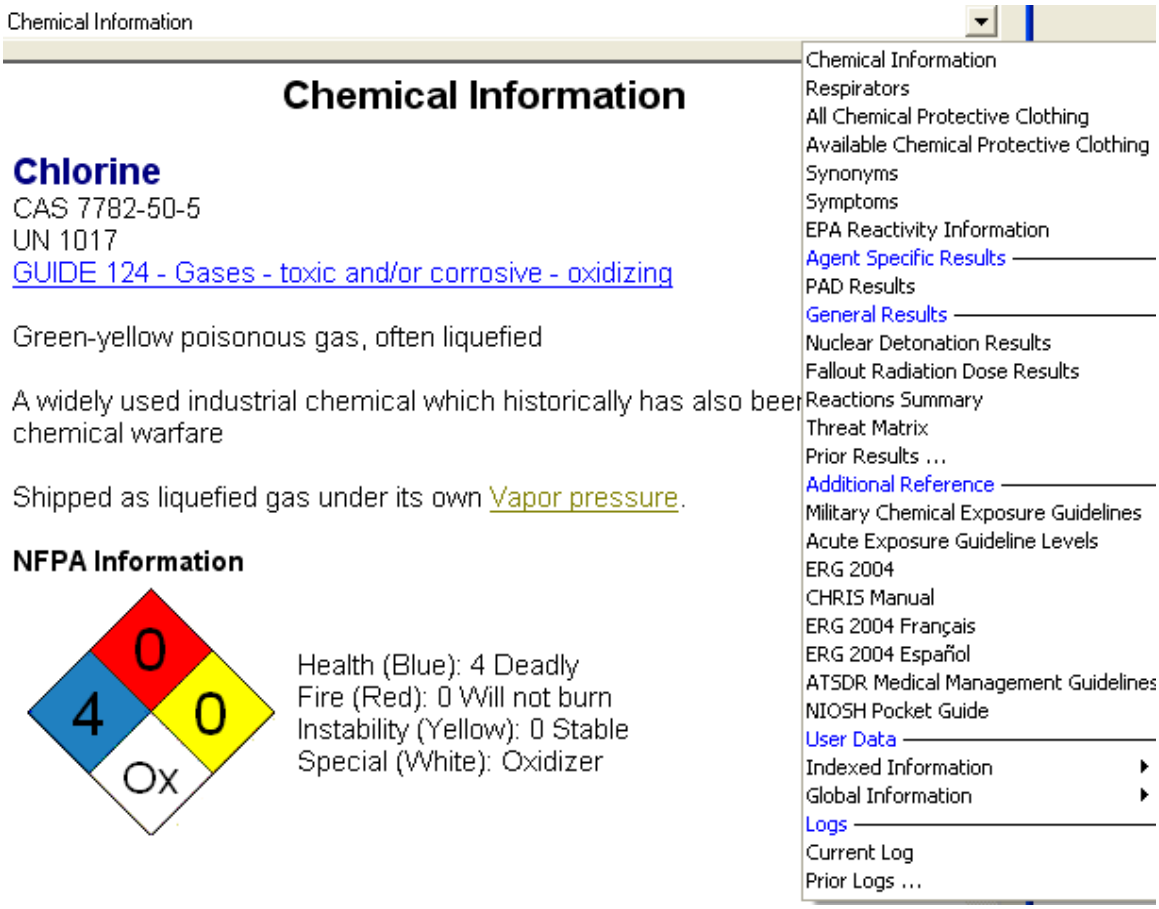
The AEGL-1 and AEGL-2 levels are also evaluated to ensure that the chemicals do not pose a greater than 0.0001 increased risk for cancer.

Source

United States Environment Protection Agency

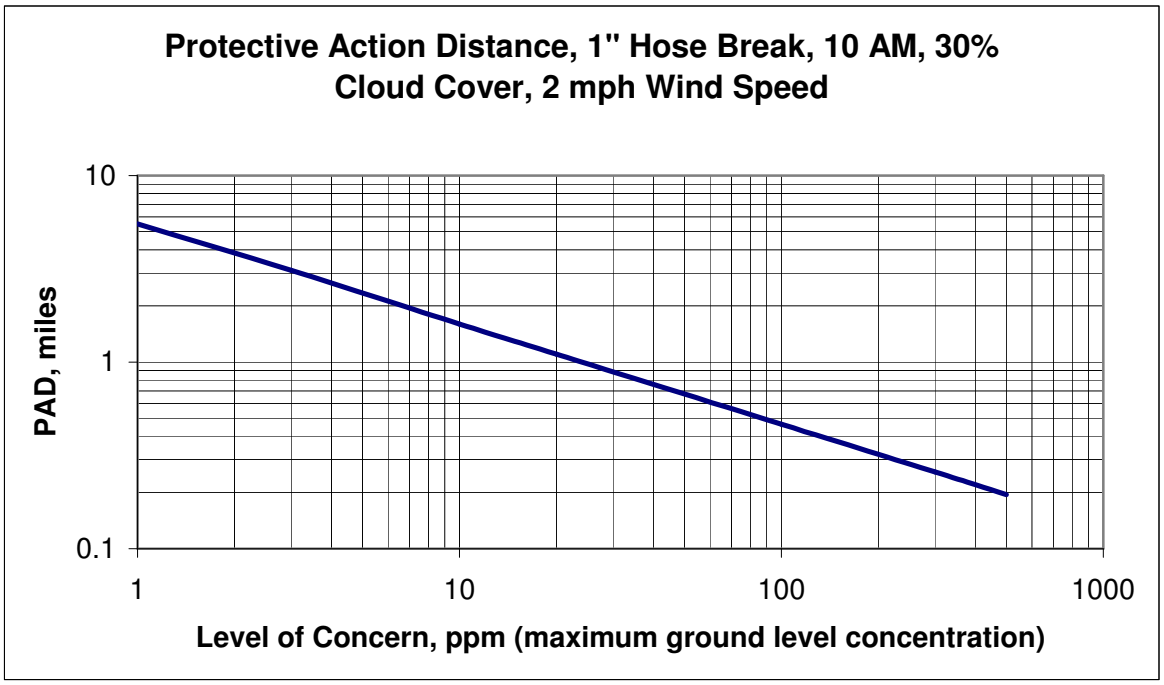
The PEAC tool has a lot of other information about chlorine. The user may select "Chemical Information" to get other information about chlorine (full display not shown) or pull up a drop down box, as shown below, to link up with additional information such as respirators protective clothing, the NIOSH pocket Guide, the 2004 Emergency Response Guidebook in English, French, or Spanish, or Medical Management Guidelines. Nuclear Detonation Results and Fallout Radiation Dose Results do not have

anything to do with chlorine, but provide a link to do these types of calculations in a hurry.



The military, for example, has exposure guidelines for deployed troops, which may encounter chlorine (or other chemicals). This information may be obtained by highlighting "Military Chemical Exposure Guidelines" in the drop-down box as shown above.

The PEAC user can record the PAD (miles) for different Levels of Concern, and plot them on a graph. If log-log paper is used, an almost straight line is achieved. The plot for say the 30% cloud Cover, 2 mph wind speed, and 1=inch chlorine transfer line break appears as below:



For distances less than 0.2 miles (1050 feet), modeling shows concentrations were lethal. Fortunately, the cloud hugged the ground near the source, as shown in the news coverage photos. People could see the toxic cloud and scamper out of the way. Further away, the cloud became more diffuse and concentrations were lower but the cloud was wider and not as visible. Sixty-three (63) people showed up at the local hospital suffering from respiratory distress.

Table 1. Effects of Chlorine on Respiratory Tract (from Ellenhorn and Barceloux, 1988)

Concentration of Chlorine, ppm	Effect of Prolonged Exposure
1 to 3 ppm	Mild mucous membrane irritation
5 to 15 ppm	Moderate irritation of upper respiratory tract
30 ppm	Immediate chest pain, vomiting, dyspnea, cough
40 to 60 ppm	Toxic pneumonitis and pulmonary edema
300 ppm	Lethal over 1 hour
430 ppm	Lethal over 30 minutes
1000 ppm	Dead within a few minutes

Ellenhorn, M.J., and D.G. Barceloux, 1988. *Medical Technology: Diahnosis and Treatment of Human Poisoning*. Elsevier science publishing Co., Inc.