CHLORINE RAIL CAR ACCIDENT, MACDONA TX

AristaTek has seen some feedback saying that analysis of real-world accidents or chemical releases is of greater interest than hypothetical scenarios.

Chlorine Release, 90-Ton Chlorine Rail Car Accident, Macdona TX, June 2004

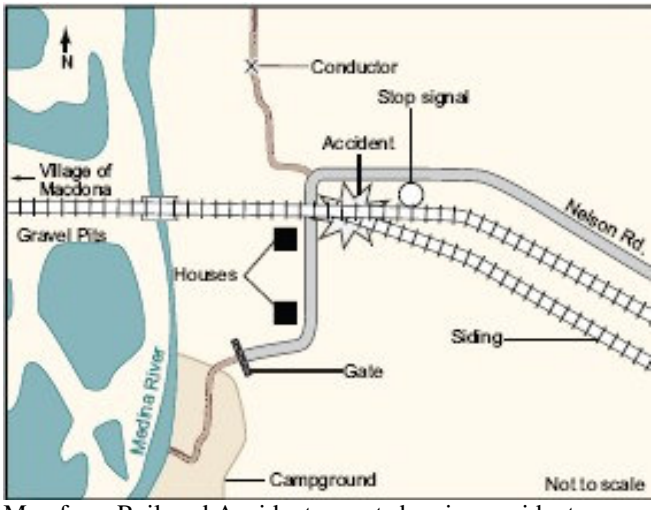
Photo from EPA-On-Scene Coordinator Website, http://www.epaosc.net/site_profile.asp?site_id=726444

On 28 June 2004, at approximately 5:03 AM, at Macdona TX, a Union Pacific train collided with a Burlington Northern (BNSF) train resulting in a derailment of four locomotives and 35 railcars. A filled 90-ton chlorine railcar was breached releasing 60 tons (120,000 lbs) of chlorine as of three days after the accident. Also released was about 78,000 gallons of urea fertilizer plus diesel fuel from the four locomotives. The train conductor was killed. Two residents in a house nearby died from chlorine inhalation. About 43 people were hospitalized from chlorine inhalation, including 6 emergency responders.

The first 911 call was received from a local resident 3 minutes after the accident (a few seconds after 5:03AM). Initial 911 callers mentioned “train derailment” or “train wreck”, and “smoke” or “difficulty breathing”, but the dispatcher(s) had difficulty picking up on the emergency calls. At 5:08 AM, one of the BNSF train crew members notified the Union Pacific train dispatcher that a UP train had come on us “fast” but was now stopped and that he would access the situation. At 5:12 AM, the Union Pacific Railroad notified the Sheriff’s Dispatcher of a possible train incident. Responders from the Southwest Volunteer Fire Department were the first to arrive on the scene at 5:15 AM, and reported driving into a “yellow cloud” of an “unknown substance”. The Southwest Volunteer Fire Department, who responded to the “medical emergency” based on 911 information were unaware of the chlorine release, and were unable to enter the area and requested mutual aid from other agencies. Some protective clothing and self-contained breathing apparatus became available, and at 5:40 AM the Fire Department entered the area to look for survivors. They found the train engineer at 6:15 AM, and transported him in the command vehicle to the fire station for decontamination. At 6:10 AM, the Bexar County Office of Emergency Management established the unified command system. The San Antonio Fire Department arrived on-scene at 6:15 AM. The hazardous materials response contractors retained by the railroad arrived at 6:33 AM and began to assess the chlorine release.

The major concern was rescue of nearby residents. However, the train derailment blocked the main road to the closest residences, and access to the rear of the residences was blocked by a flooded river. Access was also hampered by locked gates and high security fences. The only way to reach the residents was on foot. Emergency response personnel also did not have enough Personal Protective Equipment especially supplied air to enter the stricken area. Immediate rescue was therefore not feasible. The nearby residents initially were ordered via the 911 Center to shelter-in-place while a site assessment was conducted, but there were no instructions to residents of how to do this. Another problem was that radio traffic between 911 and responders was not recorded because of a malfunction. Some of the residents walked away on foot, but the people in the two closest houses were trapped inside. Evacuation began for other residences within a two-mile radius, or about 57,000 houses, based on preliminary plume modeling (about 7:15 AM), but there were conflicting reports of who should evacuate and who should shelter in place. The first attempt to enter the area of the trapped residents occurred at 9:45 AM, but the rescuers became disoriented and could not locate the houses. A second team entered the area to come to the aid of one of the entry team firefighters. A third team entered the area at 10:12 AM; they reached three residents at 10:55 AM who were in considerable respiratory distress. The two residents who had died from chlorine inhalation were reached at 11:55 AM. Six emergency responders and 23 local residents were treated for chlorine inhalation.

At a later time, 45 residents were ordered evacuated for 13 days until the railroad company finished unloading the chlorine car.



Map from Railroad Accident report showing accident location, the two houses where residents were trapped inside, and the location of the conductor's body. Two residents in the house closest to the accident died from chlorine inhalation.

Damaged Chlorine Railcar, photo taken during cleanup operations, from Railroad Accident Report.

At a public hearing, the events just before and right after the collision were reviewed (26-27 April 2005, Macdona TX, see http:www.ntsb.gov/events/2005/Macdona/iic_opening.htm). At about 5:03 AM, the Union Pacific train traveling at 45 mph struck the 63rd car behind the locomotives of the advancing BNSF train as it entered a siding track. The BNSF crew remained with the train summoning emergency responders. The Union Pacific crew, which

suffered minor injuries, exited their overturned lead locomotive and headed west away from the toxic cloud of chlorine gas from the breached rail car, along a road on the north side of the tracks. During their escape, the train conductor experienced difficulty breathing and was unable to continue away from the toxic cloud and collapsed. The train engineer was unable to carry the conductor, and he continued walking away from the cloud. The train engineer doubled back, retracing his route, and was rescued by first responders at 6:15 AM. The train conductor died. The train engineer was hospitalized for chlorine inhalation. Crew fatigue was blamed for the train collision

The chlorine gas cloud eventually reached the outskirts of San Antonio about 10 miles away.

An EPA Region 6 Emergency Response Review on the actions of all responding organizations to the accident is available at http://www.epa.gov/earth1r6/6sf/pdffiles/union_pacific_macdona_texas_response_review_final.pdf. The date of the EPA review is August 18, 2004. The Railroad Accident Report is available at http://www.ntsb.gov/Publictn/2006/RAR0603.pdf. The Railroad Accident Report also reviewed actions of responders.

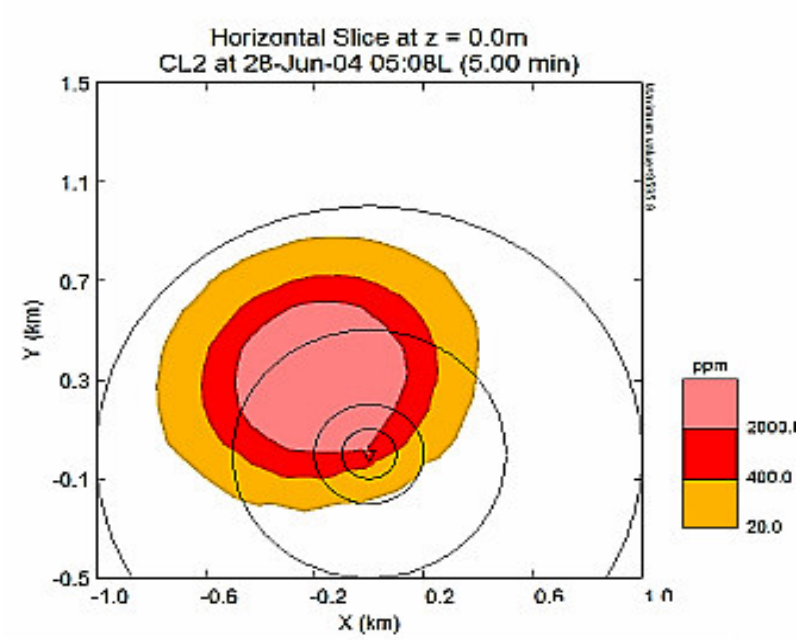
A major criticism on response operations was that although the responders arrived at the scene promptly, there was a lack of coordination between the responding agencies, and more could have been done to rescue the stricken residents sooner. The San Antonio Fire Department, the Bexar County Office of Emergency Management, and the Southwest Volunteer Fire Department were involved in what was described as a certain amount of discordant debate regarding jurisdictional boundaries and incident command authority. Based on post accident emergency debriefings and interviews with responders, no consideration was given to using open farm fields to the south of the accident site as potential helicopter landing areas or drop sites for firefighters. The firefighters could have used nearby unpaved roadways from the farm fields, which would allow them to reach the two houses on foot.

Property damage and environmental cleanup costs exceeded $7 million.

Modeling the Macdona Chlorine Release

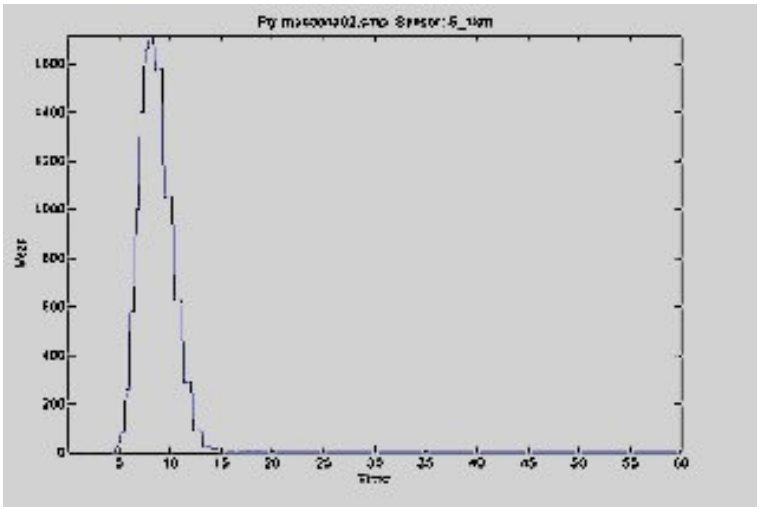
There was a mention of an initial plume modeling done about 2 or 2.5 hours after the chlorine release, which was used as a basis of a 2 mile evacuation affecting 57,000 residences, but AristaTek was not able to find any details.

Dr. Steven Hanna (Hanna Consultants) presented a paper at the Chemical Biological Information Systems conference on 10 January 2007 at Austin TX sponsored by NDIA. The paper is available at http://www.dtic.mil/ndia/2007cbis/Wednesday/hannaWed1130.pdf.



Also authoring the paper were Gene Lee, David Belonger, Peter J. Drivas, Rex Britter, and Olav Hansen. The Macdona chlorine accident was modeled using SCIPUFF. The figure at the left was presented at the conference, which shows chlorine contour concentrations at ground level 5 minutes after the release. The "pink" shows concentrations above 2000 ppm, "red" between 40 and 2000 ppm, and "yellow" between 20 and 400 ppm. Distances are in kilometers.

The SCIPUFF Model is described as a "second order closure, integrated puff dispersion model" and is available from The Tritan Corporation, Princeton NJ. As the name implies, the word "puff" implies a sudden, transitory release. The Steve Hanna paper, commenting on the choice of models as applied to releases from selected major railcar accidents, said that the models SCIPUFF, SLAB, HGSYSTEM, ALOHA, TRACE, and PHAST generally agree within a factor of two on plume parameters providing all are compared at the same source and meteorology.



The Hanna paper also presented a concentration time plot as seen by a hypothetical chlorine sensor placed 1 km downwind near or at ground level. The plot, reproduce at the left, shows mean concentration in ppm vs time in minutes. The concentration reached 1750 ppm chlorine at 1 km, 8 minutes into the release.

Unfortunately, the Hanna paper as presented at the conference did not say how much chlorine was released nor give information on the meteorology, nor did the paper provide other details essential for understanding the modeling. Therefore any comparison between the PEAC tool implies certain assumptions. If time "0" represents the time of the release, the

toxic cloud travel time based on Hanna's presentation for peak concentration calculates out to 4.7 mph. Chlorine is a dense gas which hugs the ground, and its movement would expect to be somewhat delayed, which means that the wind speed was probably about 7 mph based on an initial cloud arrival time of 5 minutes.

The Railroad Accident Report said that the San Antonio Stinson Municipal Airport located 12 miles away measured a southeast wind at 5 knots (= 5.75 mph) at 4:53 AM with a temperature of 75^{o}F and a dew point of 73^{o}F, and that the southeast winds continued for about 7 hours after the accident.

AristaTek was unable to find any record of how much chlorine was released during the early stages of the release. Remember, the first responders only knew of a train wreck and could not look into the choking, dense cloud which covered an area about 700 feet in diameter during the initial release. It was still dark at the time of the accident and when first responders arrived. Sunrise occurred at 6:37 AM. Their immediate concern was in saving lives. Hazardous material responders under contract with the railroad estimated about 60% of the original chlorine had escaped by the time they plugged the hole with wooden wedges. It took 14 days for the chlorine remaining in the tank to be removed.

Chlorine is normally a gas which is shipped under ambient temperature as a liquid at its own vapor pressure. The pressure inside the chlorine railcar depends upon the temperature. At 75^{o}F, for example, the pressure inside the railcar would be about 94 psi gage. If the pressure is suddenly released, a portion of the liquid chlorine would flash. The fraction of chlorine flashed is treated as a "puff" or sudden release, and is calculated by

$$F = C_p (T - T_b) / H$$

F = fraction of chlorine flashed
T = initial temperature inside the tank car before the breach (assume 75^{o} F)
T_b = boiling point of chlorine (use – 30^{o}F)
C_p = average heat capacity of liquid chlorine, 0.2335 Btu/lb-^{o}F
H = Heat of vaporization of chlorine, 123.7 Btu/lb

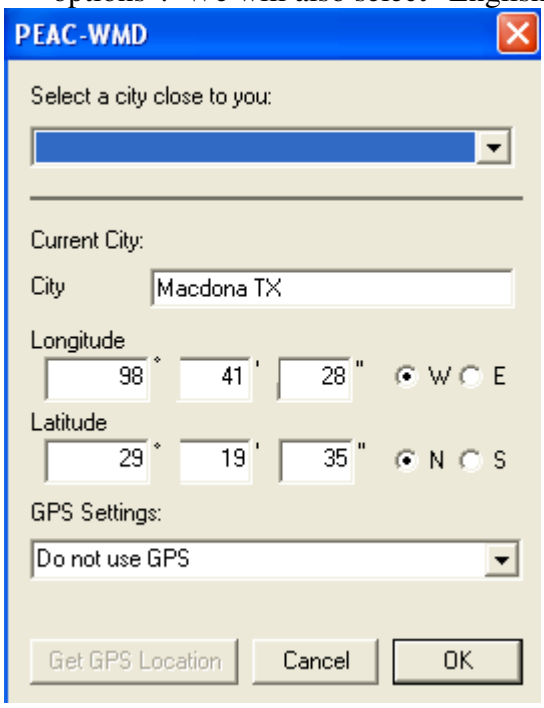
F = 0.1982

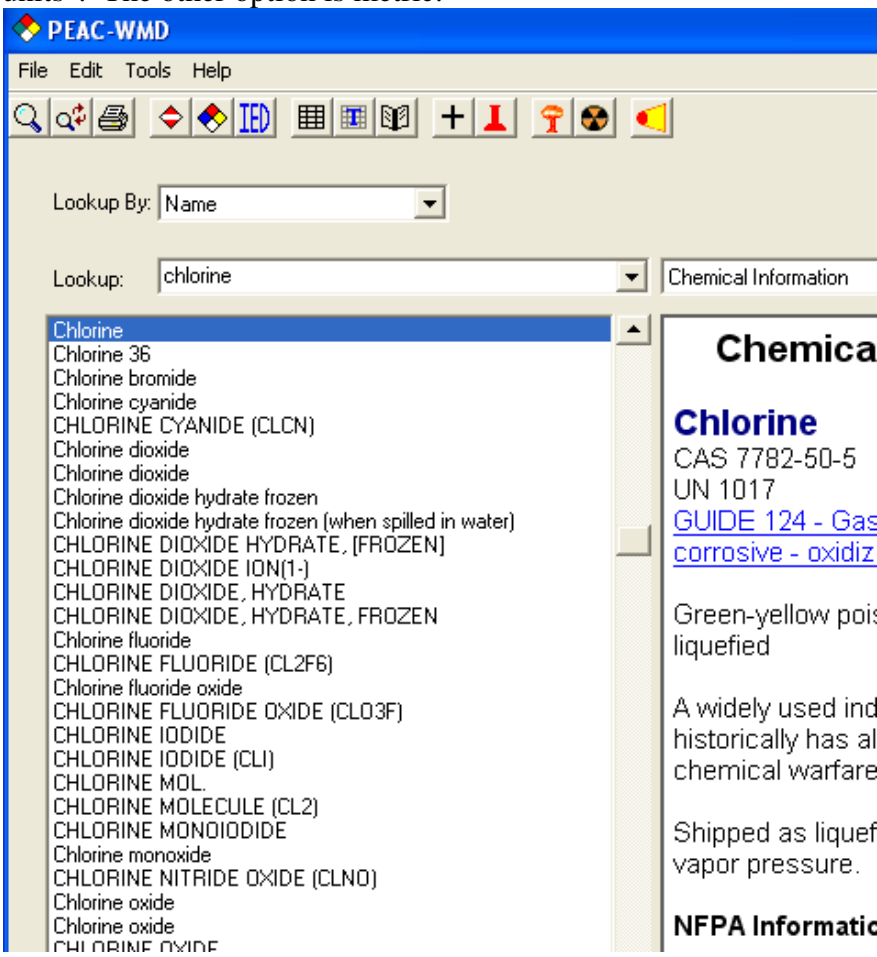
The 90-ton chlorine tank was initially full at the time of the breach according to the Railroad Accident Report. This calculates out to about 35,700 lbs flashed. In addition, there may have been some chlorine spilled onto the ground that evaporated and some chlorine aerosol entrained in the chlorine vapor cloud.

The Hanna report only modeled the initial chlorine release, probably from the liquid flash. It was evident from the accounts that chlorine continued to be released long after the hypothetical sensor concentration dropped down to zero. However, concentrations in the air while not zero should be much less than what occurred after the initial flash.

Using the PEAC Tool

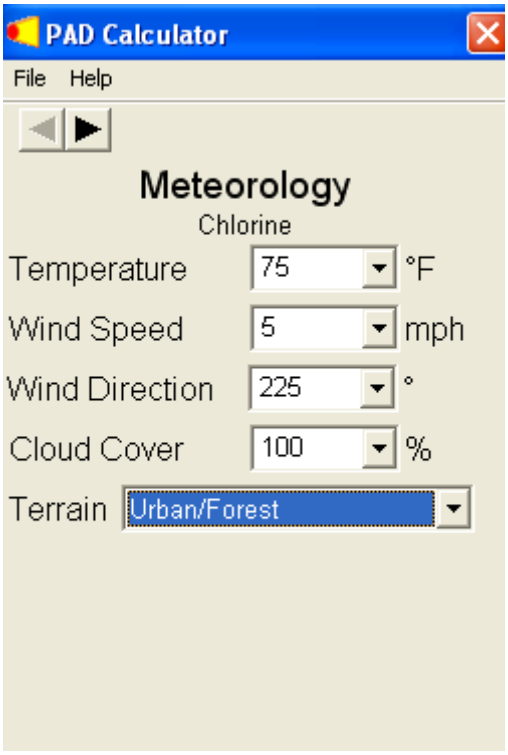
The Macdona TX accident site is located at 29.3264 north latitude (20°19'35") and 98.6911 (98°41'28") west longitude. If the PEAC user wishes to obtain an overlay of the chlorine plume cloud on a site map, this information should be entered under the pull-down screen "options". We will also select "English units". The other option is metric.

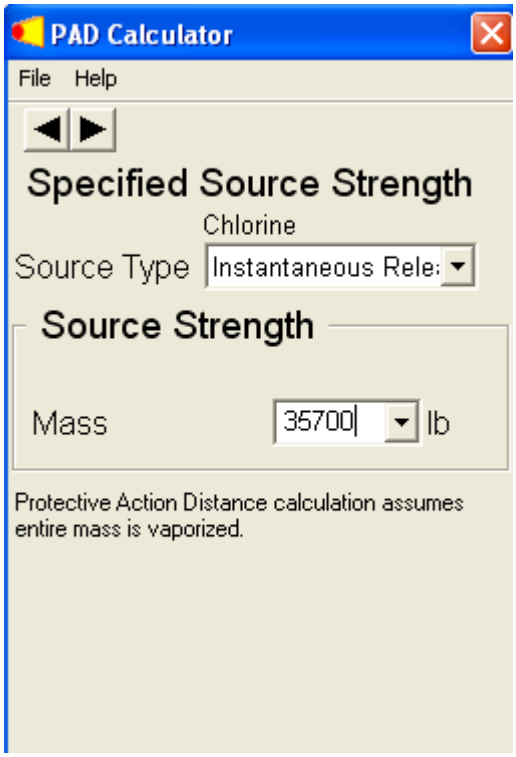




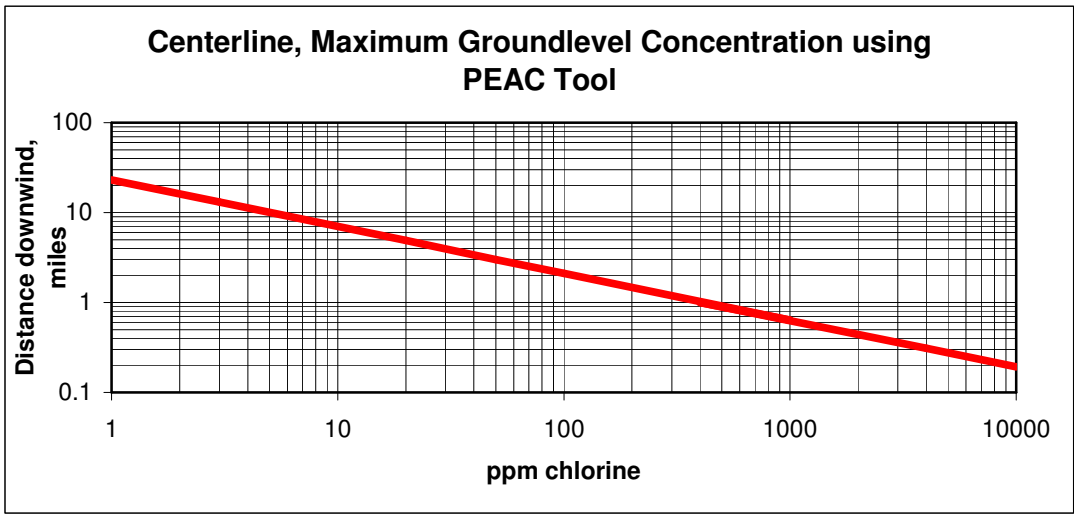
The chemical "chlorine is then selected under "Lookup". Only a portion of the display under chlorine is shown. If the user wishes to provide plume modeling for chlorine, the icon  at the upper right is started.

The PEAC display will then ask the user questions on meteorology and type of release.





The PEAC tool then asks the user the level of concern, in other words, a concentration value. The distance downwind corresponding to this concentration is calculated, near ground level at the centerline of the cloud plume. A graph of these concentrations and corresponding distances can be plotted as follows.



The Hanna paper using the SCIPUFF model predicted a maximum 1750 ppm chlorine concentration at a distance of 1 km downwind. The PEAC tool using a 35,700 lb instantaneous release predicted a downwind distance of 0.5 miles corresponding to 1750 ppm

chlorine. At 1 km (= 0.621 miles) downwind, the PEAC tool predicts a concentration of about 1400 ppm, so the PEAC predictions are in the same ballpark as Hanna's modeling. Also, the Hanna paper may have used a higher release in their modeling.

The news accounts mentioned several people in an amusement park about 10 miles downwind from the accident treated for chlorine inhalation. Fortunately, the chlorine cloud for much of its distance traveled over relatively unpopulated areas.

Levels of Concern

Perhaps most useful are the acute exposure guideline levels. The following numbers are as displayed in the PEAC tool.

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.

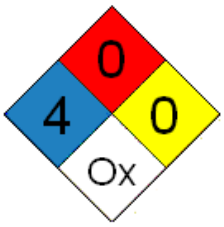
AEGL-3: The airborne concentration of a substance at or above which it is predicted that the general population including "susceptible" individuals could experience life-threatening health effects or death.

"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

Other information can be pulled up in the PEAC tool. For example,



Health (Blue): 4 Deadly
Fire (Red): 0 Will not burn
Instability (Yellow): 0 Stable
Special (White): Oxidizer

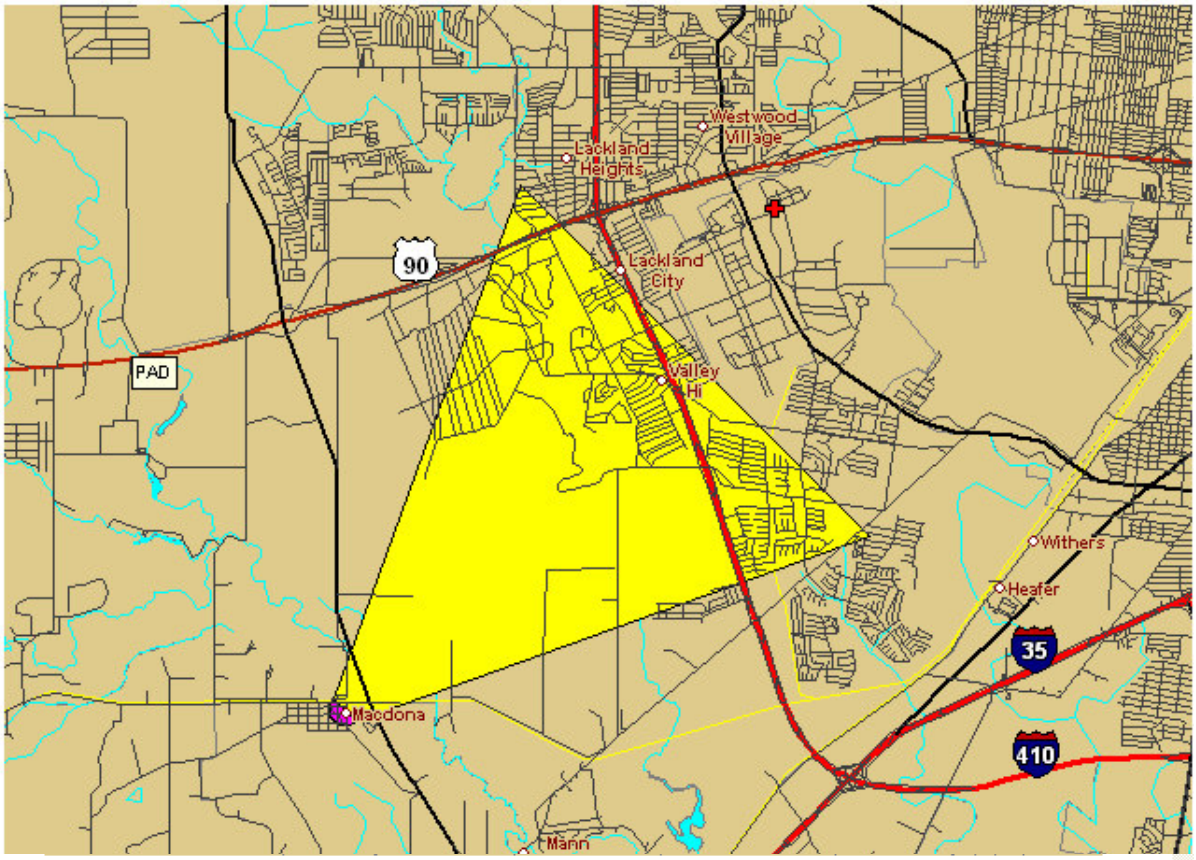
Physical and Chemical Properties
Formula: Cl_2
Molecular Weight: 71
Flash Point: Non-Combustible
Boiling Point: -29°F
Melting Point: -150°F
Rel Vapor Density @68°F: 2.5 (Heavier than air)
Vapor Pressure @68°F: 6.8 atm
Liquid Specific Gravity: 1.42 (Heavier than water)
Ionization Energy: 11.48 eV
RAE Systems PID correction factor for 11.7 eV: 1

Toxic Levels of Concern
IDLH: 10 ppm (29.04 mg/m^3)
TWA: 0.5 ppm (1.45 mg/m^3)
STEL: 1 ppm (2.9 mg/m^3)
ERPG-1: 1 ppm (2.9 mg/m^3)
ERPG-2: 3 ppm (8.71 mg/m^3)
ERPG-3: 20 ppm (58.08 mg/m^3)

The PEAC user can select a toxic level of concern and calculate a protective action distance. For example, if 20 ppm chlorine is selected, a protection action distance of 4.9 miles is calculated. This can be displayed on a map of the area.

Results

Level of Concern: 20 ppm
Initial Isolation Distance: 800 ft
Protective Action Distance: 4.9 miles



29° 19' 34.9"N 98° 41' 28.0"W Macdona, TX

Initial Isolation Distance: 800 ft
Protective Action Distance: 4.9 miles

This display does not mean that locations within the yellow triangle have concentrations of 20 ppm or greater. The actual plume cloud may be only several hundred or thousand feet wide. But the cloud can wander or drift, and winds can shift meaning that the actual path is unpredictable. The wind can shift direction. Because of unpredictability, evacuations may be done in all directions, not just downwind. The initial isolation zone distance of 800 feet displayed is based on recommendations given in the 2004 Emergency Response Guidebook for transportation accidents involving large spills, but because of the very large magnitude of the spill, responders should consider using an even greater distance.

All of this information and more can be displayed in the PEAC tool and can be transferred to a printer.