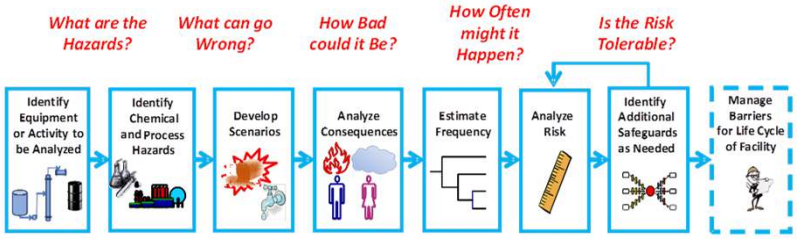
Risk Analysis Screening Tools (RAST)

Case Study – Chlorine Repackaging

DPC Enterprises – Chorine Release
Festus, Missouri
August 14, 2002

Case Study – Chlorine Rail Car

Hazard Identification and Risk Analysis (HIRA) Study



We begin the study by **Identifying the Equipment or Activity** for which we intend to perform an analysis. RAST uses the operation of a specific equipment item containing a specific chemical or chemical mixture to define the activity. For example, the operation of a storage tank, a reactor, a piping network, etc. Inputs are chemical data, equipment design information, operating conditions, and plant layout.

Case Study – Chlorine Repackaging

Process Description

We have been asked to perform a HIRA study of a chlorine repackaging facility. The DPC Enterprises facility in Festus Missouri repackages chlorine from railcars into smaller containers. DPC captures chlorine vented from these operations in one of two caustic scrubbers that also produce household bleach for sale as a byproduct.

The chlorine repackaging operation involves the following:

- Connecting a 90-ton (180,000 pounds) chlorine tank car to one of three unloading stations.
- Transferring liquid chlorine from the tank car through the process piping system to filling stations.
- Loading the filled 150-pound cylinders and 1-ton containers onto trucks for distribution.
- Cleaning and preparing empty cylinders and containers for reuse.

In addition to repackaging chlorine, the Festus facility also runs a continuous bleach manufacturing process. We will start with the chlorine railcar unloading operation

This is an illustrative example and does not reflect a thorough or complete study.

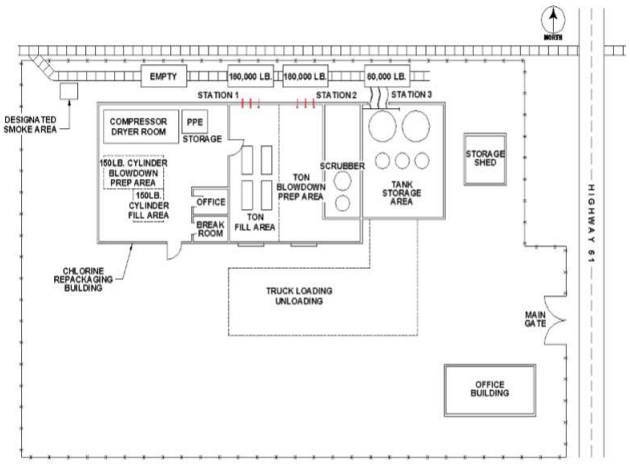
Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – Chlorine Repackaging

Process Description

Tank cars are brought into the facility through a rail spur along the northwest corner of the site. A storage area located on the eastern side of the repackaging building contains several bulk storage tanks of sodium hydroxide (caustic soda), bleach, and wastewater. The three chlorine tank car unloading stations are located along the northern side of the repackaging building.

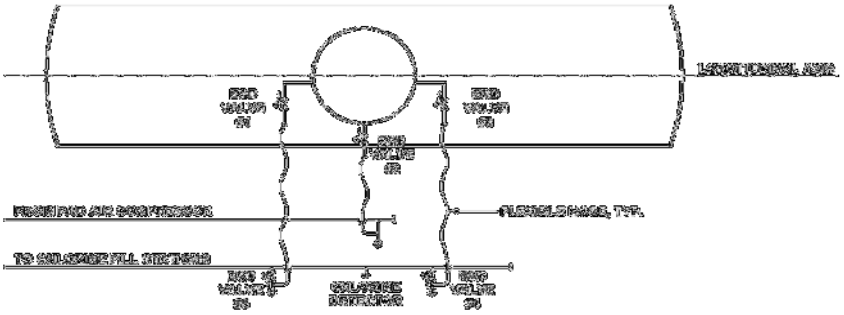
Pad air is used to help push the liquid chlorine out of the tank car into the plant piping. An eduction pipe is used to unload liquid material. It is a long steel pipe attached to the liquid valve and extends to the bottom of the tank car.



Case Study – Chlorine Repackaging

Process Description

Each unloading station is equipped with three chlorine transfer hoses, each approximately 11 feet in length and 1 inch in diameter. The chlorine system is designed to shut off accidental releases utilizing chlorine detectors and automatic air-actuated ball valves. These valves may be activated either automatically or manually by pressing one of several Emergency Shut Dow buttons located throughout the facility. Hoses remain pressurized to approximately 8 bar (115 psig) throughout normal operations although flow is stopped during breaks and lunch.



Risk Analysis Screening Tools (RAST)

Case Study – Chlorine Repackaging

We will start by entering information for chlorine rail car. At some point, we may decide to include other equipment associated with the facility in the study.

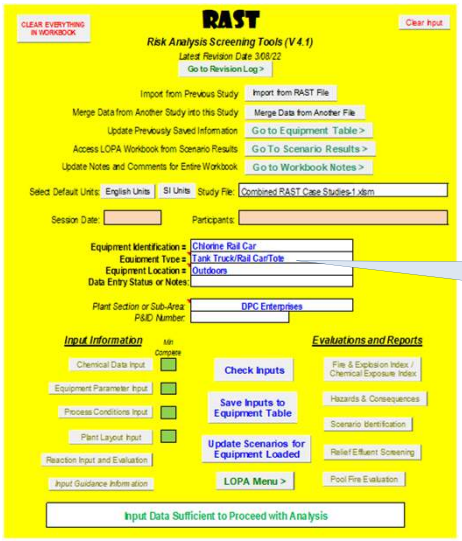
One the Main Menu, enter the equipment identification as the **Chlorine Rail Car**, equipment type as **Tank Truck/Rail Car/Tote** and location as **Outdoors**.

Chemical Data – RAST requires a chemical or chemical mixture that is representative of the hazards. RAST does not perform time-dependent or location-dependent composition changes (such as within a reactor or distillation column). In this example, we will merely enter chlorine as the chemical.

Risk Analysis Screening Tools (RAST)

Case Study – Chlorine Repackaging

Begin by entering information on the Main Menu worksheet. Start with the Chlorine Rail Car.



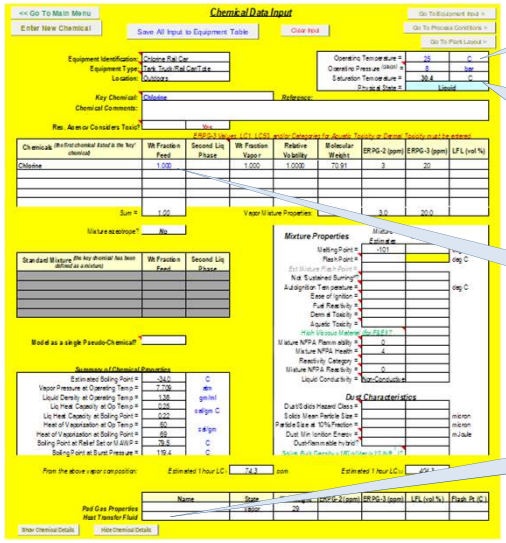
Enter Equipment Identification, Equipment Type and Location

Case Study – Chlorine Repackaging

Chemical Data

The chemical name is entered as chlorine and the weight fraction as 1.0

The operating pressure was entered as 8 barg and the operating temperature is entered at 25 C. That that units may be changed such as an operating pressure of 115 psig and operating temperature of 77 F.



The operating pressure and temperature

Saturation temperature is displayed and physical state as "liquid"

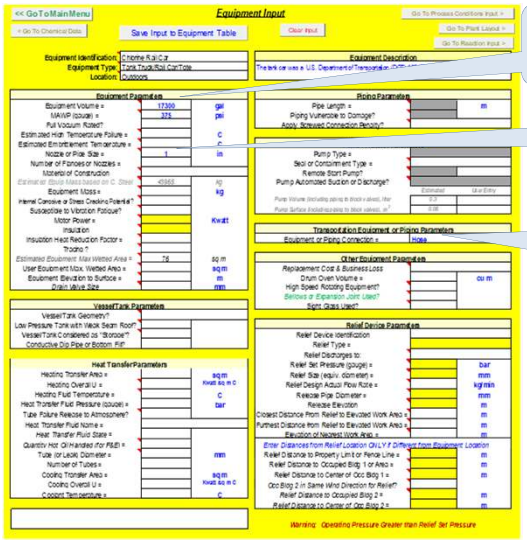
RAST allows up to 5 components.

Chemical details may be shown or hidden

Case Study – Chlorine Repackaging

Equipment Input

A chorine rail car contains a maximum of 82000 kg chlorine (90 m^3 or 17300 gal). The maximum allowable working pressure is 26 barg or 375 psig. Liquid connections are 1 inch.



The equipment volume and maximum allowable working pressure

A largest "working" nozzle of 1 inch is entered

A connection type of "Hose" is also entered.

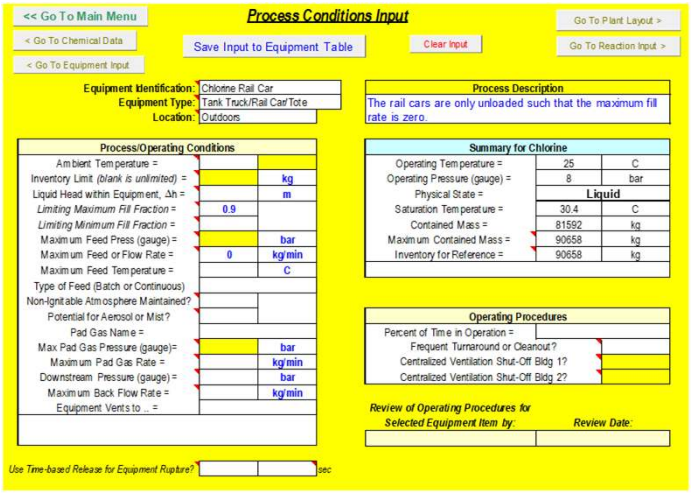
Case Study – Chlorine Repackaging

Process Conditions

The maximum flowrate to the railcar is zero as railcars are only unloaded at this facility.

A 0.9 maximum fill fraction is entered as the rail car is received approximately 90% full (versus the default 80% if the entry is blank).

The default ambient temperature of 25 C has been assumed (based on no entry for ambient temperature).

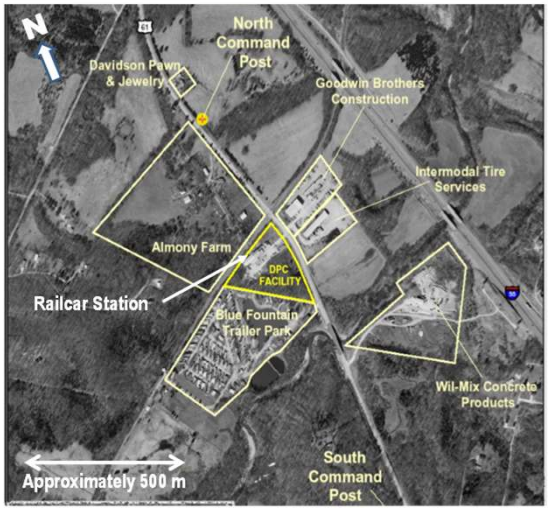


Case Study – Chlorine Repackaging

Site Layout

In addition to the site office building 50 m south of the rail car station (~ 5 occupants), various businesses and residential areas surround the DPC Festus facility:

- Blue Fountain residential mobile home park, consisting of about 100 homes, is approximately 100 m southwest.
- Goodwin Brothers Construction and Intermodal Tire Retreading are located about 100 to 200 m to the east, separated from DPC by Highway 61. Each business has about 18 full-time employees.
- Interstate 55 is located less than 0.5 mile to the east



Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – Chlorine Repackaging

Site Layout

RAST allows for entry of two offsite populated areas referred to as Zone 1 and beyond Zone 1. Zone 1 begins at the "Distance to Property Limit" extends to "Distance to End of Zone 1" on the Plant Layout worksheet.

A free software program, MARPLOT (from the US EPA), may be used to determine population density in the United State. Outside the US or where data is not available from MARPLOT, the following pictures give an idea of offsite population density.

Examples of Sparsely populated areas

5E-5 people/m^2
Rural homes/farms

2E-4 people/m^2
Residential homes on very large plots

Case Study – Chlorine Repackaging
Site Layout

Examples of Moderately populated areas ***Examples of Densely populated areas***

1.5E-3 people/m²
Typical suburban residential area

3E-4 people/m²
Mobile Homes (upper end of Moderate)

4E-3 people/m²
Very closely spaced single family dwellings

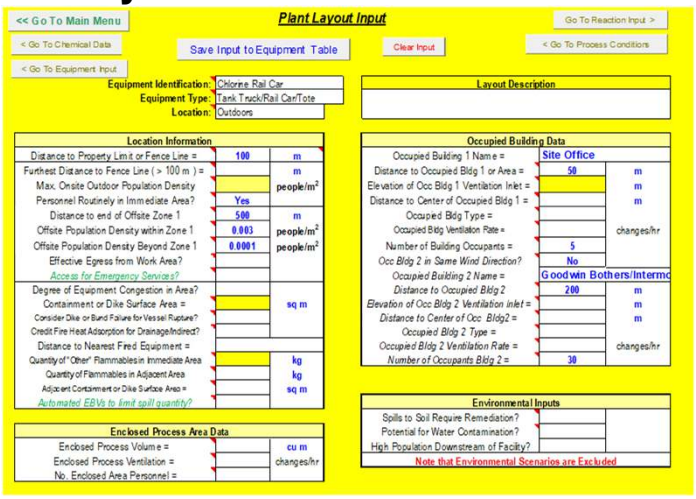
4E-3 people/m²
Multifamily dwellings – 2 story apartments and duplexes

5E-3 people/m²
Multifamily dwellings – multi-story apartments closely spaced

Case Study – Chlorine Repackaging
Site Layout

The Blue Fountain mobile home park (noted as Zone 1) is located adjacent to the DPC property and extends to approximately 500 m from the rail car station. The population density is higher than a typical residential area at roughly 0.003 people/m². The region beyond the mobile home park (in the same wind direction) denoted as beyond Zone 1 is rural with a very low population density (maybe 0.00005 people/m²).

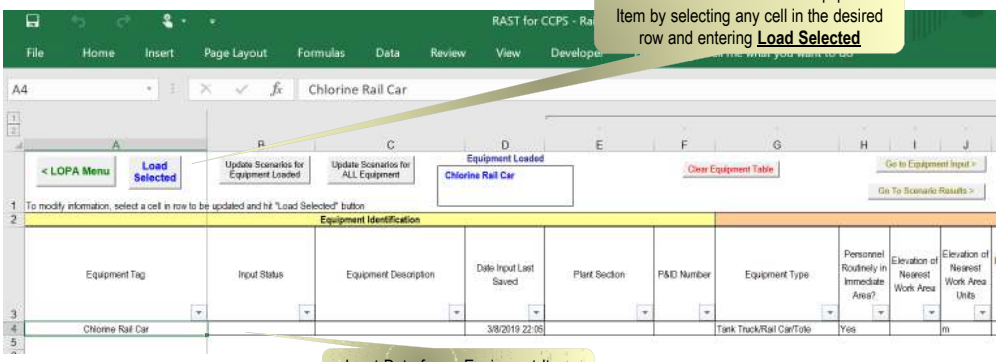
The site office and offsite businesses are entered as occupied buildings.



Risk Analysis Screening Tools (RAST)

Case Study – Chlorine Repackaging

Select <u>Save Inputs to Equipment Table</u> (blue macro button). All Input Information will be stored in the Equipment Table in a single row identified by a unique Equipment Identification or Tag.



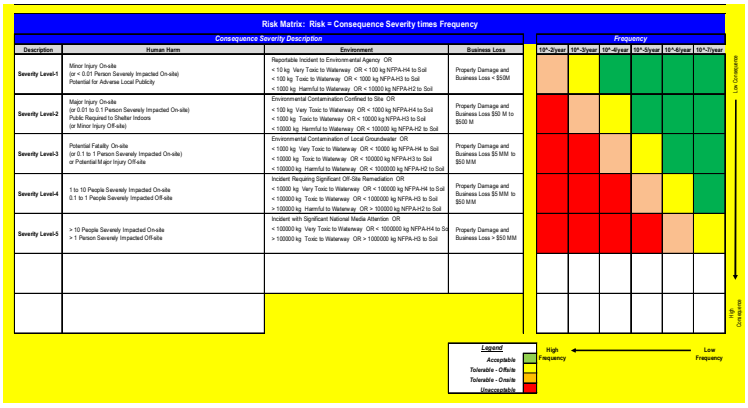
Risk Analysis Screening Tools (RAST) Overview / Demonstration

Risk Analysis Screening Tools (RAST)

Risk Matrix

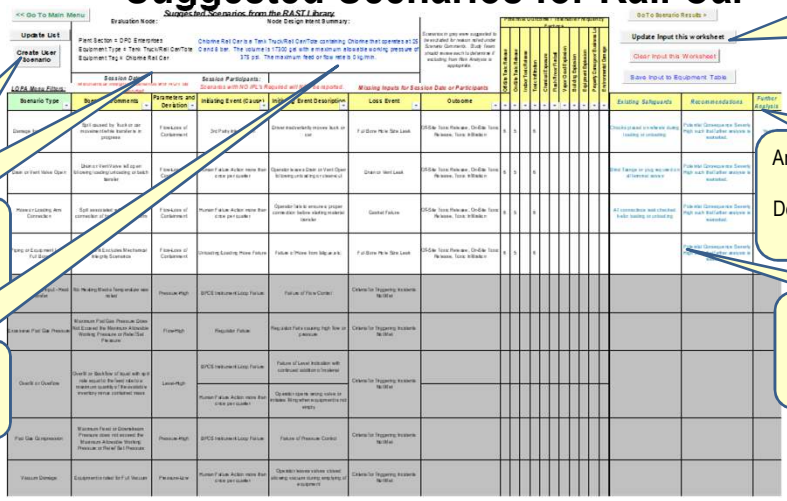
To understand the Consequence Severity and Tolerable Frequency, the values for key Study Parameters and a Risk Matrix may be viewed on the Workbook Notes worksheet. These values may be updated on hidden worksheets and should reflect the company's specific risk criteria.

For this case study, the Risk Matrix (right) has been used. The Human Harm criteria is based on an estimated number of people severely impacted (severe injury including fatality).



Case Study – Chlorine Repackaging

Suggested Scenarios for Rail Car



Additional Scenarios are Added using "Create User Scenario"

Evaluation Date(s) and Participant Names are entered on the Main Menu

Draft Design Intent Statement for updating by the Evaluation Team

Once Inputs are Entered use "Update Input this Worksheet" to Save

Analysis Team captures which Scenarios warrant more Detailed Evaluation (Layers of Protection Analysis)

Analysis Team captures Existing Safeguards and Recommendations for Scenarios Identified

Note that Mechanical Integrity (Residual Failures) have been excluded for the listing based on entering "Yes" to "Exclude MI Scenarios?" on the LOPA Menu worksheet.

Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – Chlorine Repackaging

Suggested Scenarios for the Rail Car

WORKING WITH YOUR EVALUATION TEAM:

- ❑ **Review the suggested list of scenarios. Do these represent what you would expect for a rail car during unloading operation?**
- ❑ **Are there scenarios that have been "screened out" (shown in gray) that should be considered?**
- ❑ **Are there scenarios missing? (Possibly similar scenarios with different Initiating Events)**
- ❑ **Do you agree with the "worst" Consequence (Tolerable Frequency Factor) for the scenario listed?**

Case Study – Chlorine Repackaging
Suggested Scenarios for the Rail Car

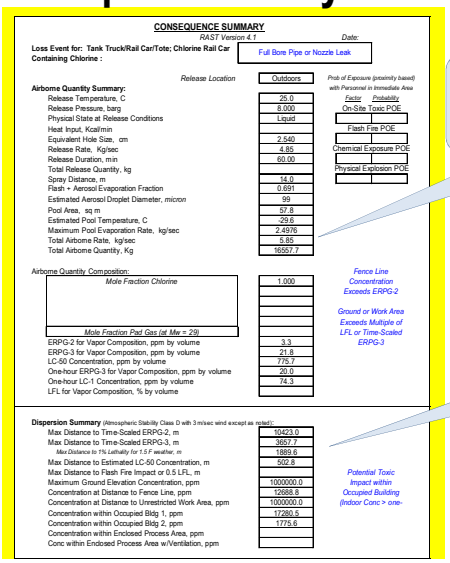
WORKING WITH YOUR EVALUATION TEAM:

- ❑ **Utilize an Appropriate Hazard Evaluation Technique (HAZOP, What If, etc.) to capture additional scenarios.**
- ❑ **Capture existing Safeguards and Recommendations for each Scenario. Note the Dates and Names of participants in the Study.**
- ❑ **Select which Scenarios warrant more detailed Risk Evaluation (such as Layers of Protection Analysis).**

Case Study – Chlorine Repackaging
Consequence Analysis

For the Rail Car, select **Full Bore Pipe or Nozzle Leak** as the Loss Event. This provides a "worst" Consequence for a total hose failure.

The distance to ERPG-2 is estimated in RAST to be nearly 10000 m or 6.5 miles. Adjusting for the actual 2 m/sec wind speed at the time of the incident, and a vapor rate of 2 kg/sec due to flow restrictor, the distance to ERPG-2 would have been estimated at 4.5 miles which is in good agreement to CPB modeling of 3.7 miles.



CONSEQUENCE SUMMARY

RAST Version 4.1 Date:

Loss Event for: Tank Truck/Rail Car/Tote; Chlorine Rail Car Containing Chlorine : Full Bore Pipe or Nozzle Leak

	Release Location: Outdoors
Airborne Quantity Summary:	
Release Temperature, C	25.0
Release Pressure, barg	8.000
Physical State at Release Conditions	Liquid
Heat Input, Kcal/min	
Equivalent Hole Size, cm	2.540
Release Rate, Kg/sec	4.85
Release Duration, min	60.00
Total Release Quantity, kg	
Spray Distance, m	14.0
Flash + Aerosol Evaporation Fraction	0.691
Estimated Aerosol Droplet Diameter, micron	99
Pool Area, sq m	57.8
Estimated Pool Temperature, C	29.6
Maximum Pool Evaporation Rate, kg/sec	2.4976
Total Airborne Rate, kg/sec	5.85
Total Airborne Quantity, Kg	16557.7
Airborne Quantity Composition:	
Mole Fraction Chlorine	1.000
Mole Fraction Pad Gas (at Mw = 29)	
ERPG-2 for Vapor Composition, ppm by volume	3.3
ERPG-3 for Vapor Composition, ppm by volume	21.8
LC-50 Concentration, ppm by volume	775.7
One-hour ERPG-3 for Vapor Composition, ppm by volume	20.0
One-hour LC-1 Concentration, ppm by volume	74.3
LFL for Vapor Composition, % by volume	

Prob of Exposure (proximity based) with Personnel in Immediate Area: Factor / Probability

On-Site Toxic POE

Flash Fire POE

Chemical Exposure POE

Physical Explosion POE

Fence Line Concentration Exceeds ERPG-2

Ground or Work Area Exceeds Multiple of LFL or Time-Scaled ERPG-3

Dispersion Summary (Atmospheric Stability Class D with 3 m/sec wind except as noted):	
Max Distance to Time-Scaled ERPG-2, m	10423.0
Max Distance to Time-Scaled ERPG-3, m	3657.7
Max Distance to 1% Lethality for 1.5 F weather, m	1889.6
Max Distance to Estimated LC-50 Concentration, m	502.8
Max Distance to Flash Fire Impact or 0.5 LFL, m	
Maximum Ground Elevation Concentration, ppm	1000000.0
Concentration at Distance to Fence Line, ppm	12688.8
Concentration at Distance to Unrestricted Work Area, ppm	1000000.0
Concentration within Occupied Bldg 1, ppm	17280.5
Concentration within Occupied Bldg 2, ppm	1775.6
Concentration within Enclosed Process Area, ppm	
Conc within Enclosed Process Area w/Ventilation, ppm	

Potential Toxic Impact within Occupied Building (Indoor Conc > one-

The leak rate estimated by CSB was approximately 2 kg/sec, somewhat less than a full bore "flashing liquid" failure..

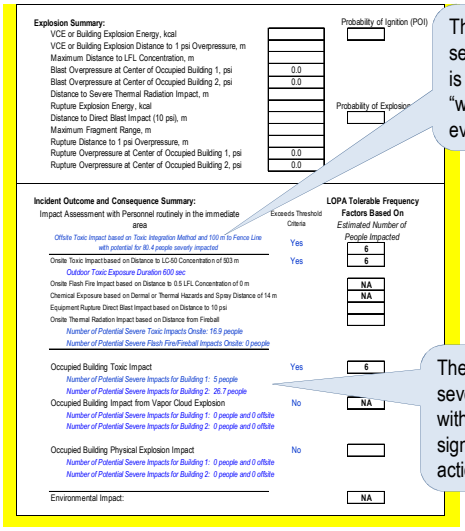
The actual wind speed was nearly 2 m/sec. Wind speed, atmospheric stability, and surface roughness are Administrative Parameters that may be adjusted on hidden worksheets.

Case Study – Chlorine Repackaging

Consequence Analysis

The estimated number of severely impacted people (potential fatalities) is 5 onsite and 27 for the offsite occupied businesses *or* 80 in the trailer park for wind in the "worst" direction. Fortunately the wind was away from the trailer park (and most residents were at work rather than home) and not directly toward nearby businesses. Onsite personnel within the site office and nearby occupied businesses were able to evacuate quickly.

In the actual incident, there were no fatalities but 63 people sought medical attention and hundreds sheltered in place for up to four hours.



The estimated number of people severely impacted in the residential area is highly inaccurate and represents a "worst" case assuming no effective evasive actions or effective safeguards.

The estimated number of people severely impacted (likely fatalities) within the occupied buildings is significant depending on any evasive actions that many have been taken.

Risk Analysis Screening Tools (RAST) Overview / Demonstration

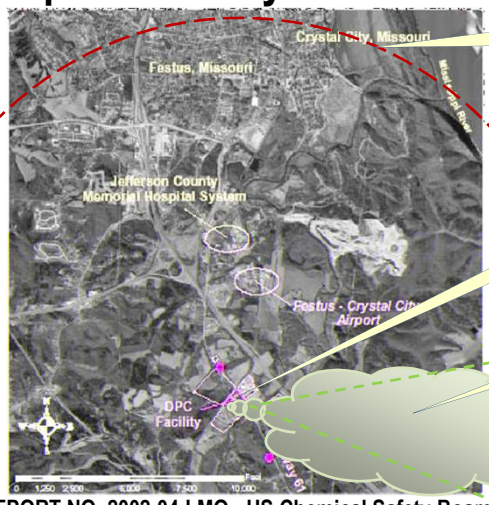
Case Study – Chlorine Repackaging

Consequence Analysis

A simplification in RAST is wind direction toward the highest population. This is quite reasonable in Risk Analysis where the wind direction is unknown.

In the actual incident, the wind direction was toward the east southeast rather than southwest toward the trailer park or directly toward the nearby businesses.

Wind Direction represents a key difference between estimates for Risk Analysis versus Incident Investigation.



3.6 mile radius to ERPG-2 concentration

Release Point – Rail Spot # 3

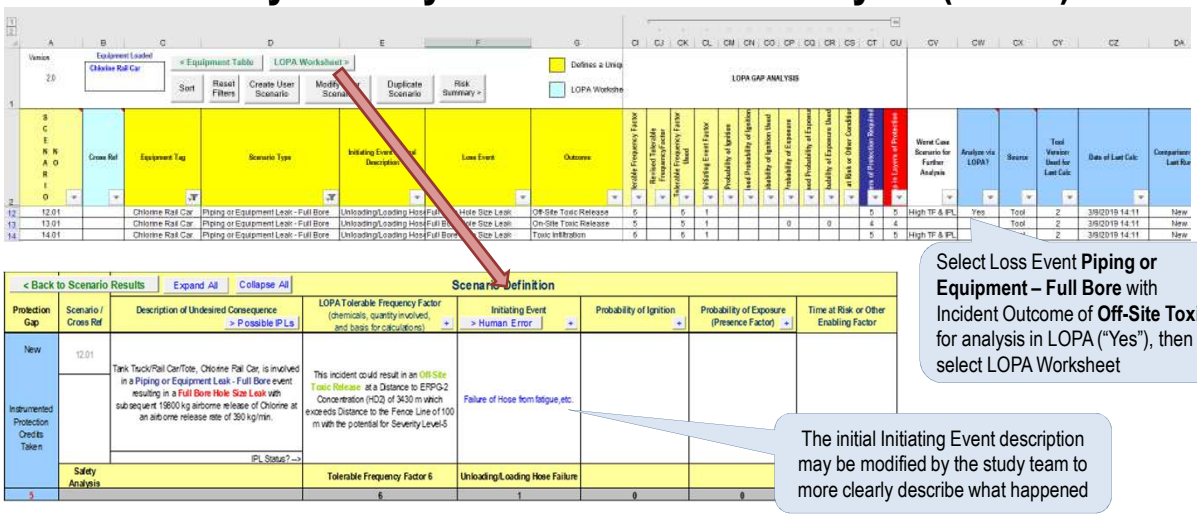
Estimated Cloud plume in RAST

REPORT NO. 2002-04-I-MO , US Chemical Safety Board

Figure 6. Aerial view of DPC Festus facility and surrounding area.

Case Study – Chlorine Repackaging

Risk Analysis / Layers of Protection Analysis (LOPA)



Select Loss Event **Piping or Equipment – Full Bore** with Incident Outcome of **Off-Site Toxic** for analysis in LOPA ("Yes"), then select LOPA Worksheet

The initial Initiating Event description may be modified by the study team to more clearly describe what happened

Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – Chlorine Repackaging

Risk Analysis / Layers of Protection Analysis (LOPA)

< Back to Scenario Results | Expand All | Collapse All | Scenario Definition

Protection Gap	Scenario / Cross Ref	Description of Undesired Consequence > Possible IPLs	LOPA Tolerable Frequency Factor (chemicals, quantity involved, and basis for calculations)	Initiating Event > Human Error	Probability of Ignition	Probability of Exposure (Presence Factor)	Time at Risk or Other Enabling Factor
New	12.01	Tank Truck/Rail Car/Tote, Chlorine Rail Car, is involved in a Piping or Equipment Leak - Full Bore event resulting in a Full Bore Hole Size Leak with subsequent 19800 kg airborne release of Chlorine at an airborne release rate of 390 kg/min. IPL Status? -->	This incident could result in an Off-Site Toxic Release at a Distance to ERPG-2 Concentration (HD2) of 3430 m which exceeds Distance to the Fence Line of 100 m with the potential for Severity Level-5	Failure of Hose from fatigue,etc.			The hose is leak checked prior to each use such that a time at risk may be appropriate. 2000 hours use per year operation of 8760 hours or 23% of time. As the greatest risk is likely the trailer park, greater than 40% of residents are not home during repackaging operation. Total factor 0.4
Instrumented Protection Credits Taken	Safety Analysis		Tolerable Frequency Factor 6	Unloading/Loading Hose Failure			USER DEFINED Enabling Factor = 1
1			6	1	0	0	1

A time at risk enabling condition of the leak occurring only during a 2000 hour operation per 8760 hour year may be appropriate if the hoses are checked daily for leaks. A conditional modifier for personnel presence to represent that most trailer park occupants are not present during weekdays may also be appropriate. The combination of these factors could reduce the scenario frequency or severity of consequences by a factor of 10 depending on company specific protocol.

Case Study – Chlorine Repackaging

Risk Analysis / Layers of Protection Analysis (LOPA)

	Not Allowed								
BPCS Control or Human Response to Alarm	BPCS Control or Human Response to Alarm	SIS Function A	SIS Function B	Pressure Relief Device	SRPS 1	SRPS 2	SRPS 3	Notes / Comments	Issues to Resolve
Operator responds to audible alarm from chlorine detectors at 5 ppm and closes a manual valve.		Chlorine detectors close automated block valves when the concentration reaches 10 ppm.			Excess flow valve closes at 15,000 lb/hour chlorine flow. However leak rate of less than 15,000 lb/hour is not likely sufficient to reduce the consequence by one severity level (or 0.1)				
Human Response to Abnormal Condition Alarm > 1/4 hr to respond		SIS - SIL 2							
1		2							

The existing safeguards may not have been sufficient for managing this scenario to a tolerable risk level. The chlorine sensor system is shared between the BPCS alarm and a SIL-2 SIS interlock but may not have been designed to this level of reliability. The block valves could be operated manually or via an emergency shutdown "button" but may be the same values for both the BPCS and the SIL-2 SIS and not be sufficiently reliable. Finally, the Excess Flow Valve may not effective as it addresses leaks less than 15000 lb/hour for which there remains a significant consequence severity.

Risk Analysis Screening Tools (RAST)

Case Study – Chlorine Repackaging

Risk Analysis and Incident Investigation often use similar methods to better understand the scenario. Risk Analysis "anticipates" what could go wrong and what the "worst" potential consequences may be. For Incident Investigation, the Incident Outcome and Consequences are known in addition to the actual weather conditions and wind direction.

For the Chlorine Rail Car, RAST did suggest hose failure as one of many scenarios to consider. RAST also recognized that an Off-Site Toxic Impact could be a feasible Incident Outcome for this loss event. RAST was conservative in estimating the number of people severely impacted as actual wind direction was not toward the highest population. A key question is "Could the consequences been much worse if wind and other conditions would have been different?"

Questions?