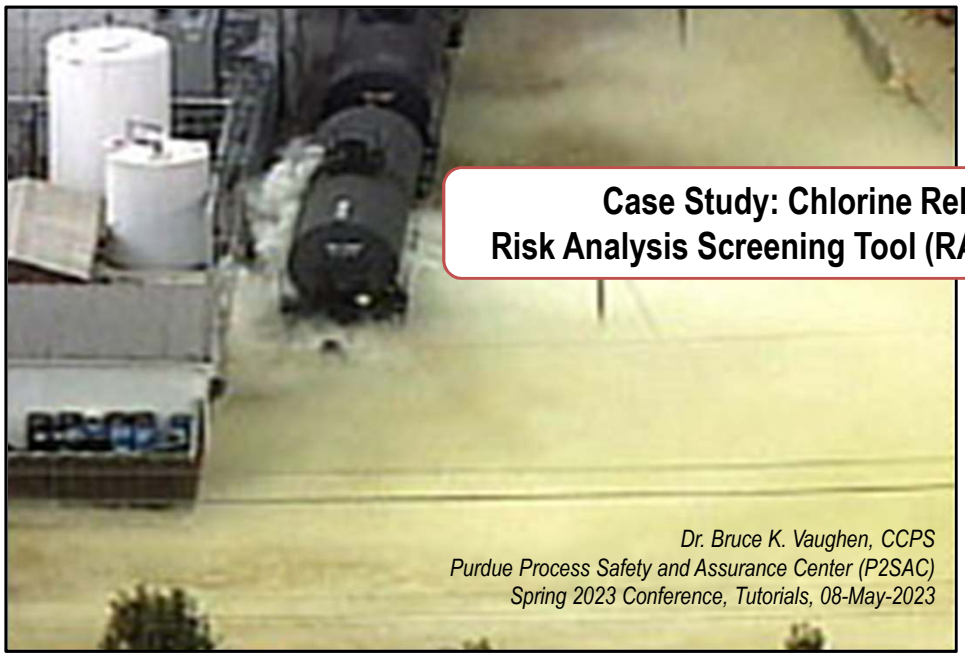

Case Study: Chlorine Release
Risk Analysis Screening Tool (RAST) Tutorial

DPC Enterprises
Festus, Missouri USA
August 2002

Dr. Bruce K. Vaughen, CCPS
Purdue Process Safety and Assurance Center (P2SAC)
Spring 2023 Conference, Tutorials, 08-May-2023

07-May-2023, Version 2

Acknowledgement

The Risk Analysis Screening Tool
The Dow Chemical Company

RAST

Ken First, Retired, The Dow Chemical Company
CCPS Consultant
Kevin Hersey, formerly at The Dow Chemical Company

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RAST Tutorial Outline

Background

- Hazard Identification and Risk Analysis (HIRA)
- Anatomy of an Incident
- Bow Tie Model

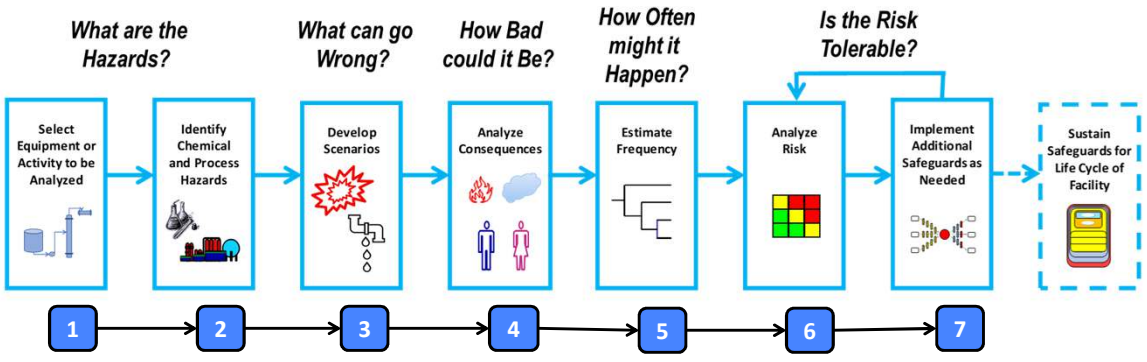
Incident Case Study – Chlorine Release

- Software orientation
- Process description
- Input minimum data using HIRA steps
- Compare to CSB results
- RAST versus incident inputs

3

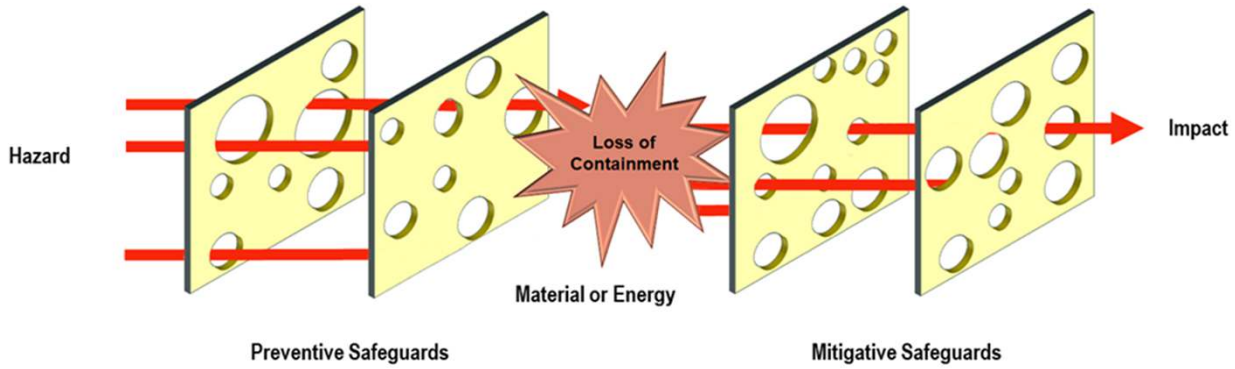
Hazard Identification and Risk Analysis (HIRA)

Five Questions and Seven Steps



4

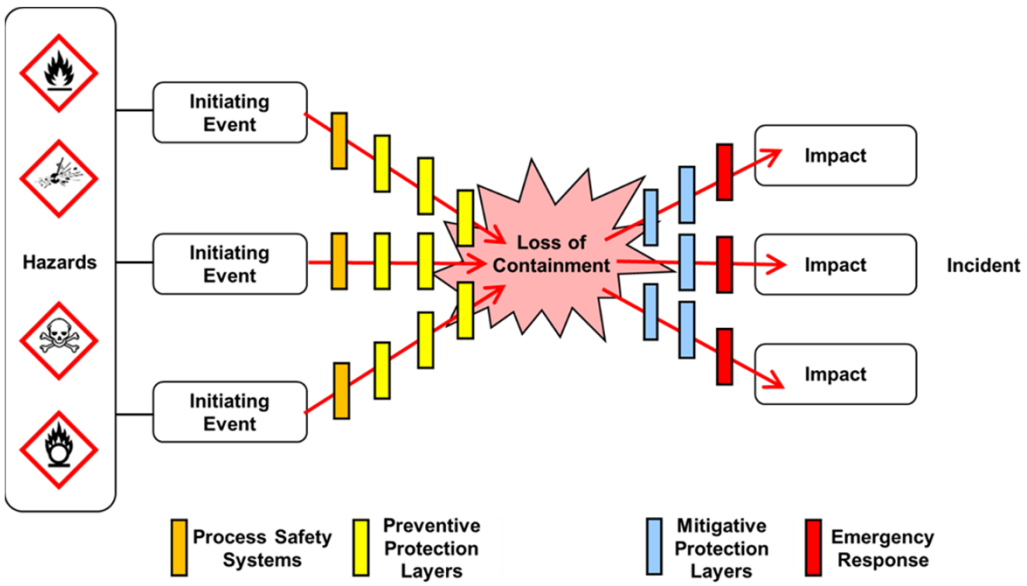
Anatomy of an Incident



Cause — Consequence — Impact: People, Environment, Property, Business

5

Bow Tie Model



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Risk Analysis Screening Tool (RAST)

Incident Case Study – Chlorine Release

Goal: To use an incident case study to show some of the decisions a Process Hazards Analysis (PHA) Team can make when using the RAST software during their review.

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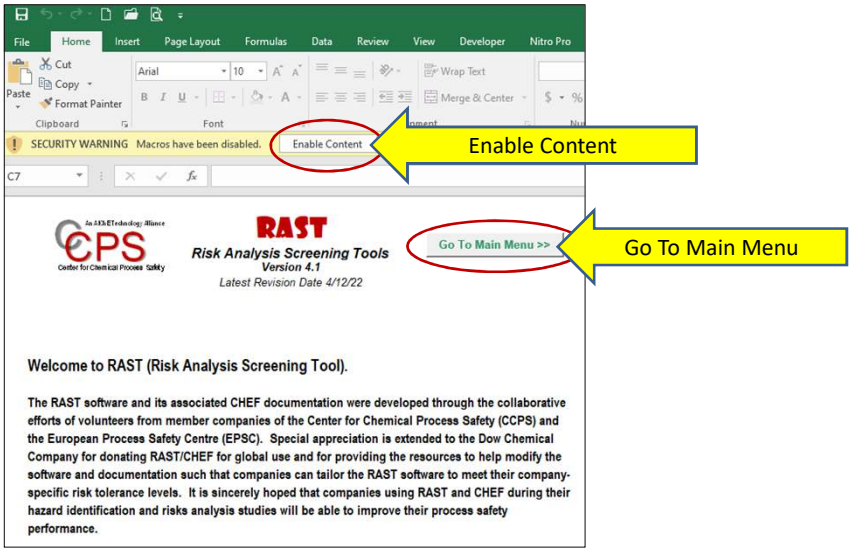
Open RAST Software



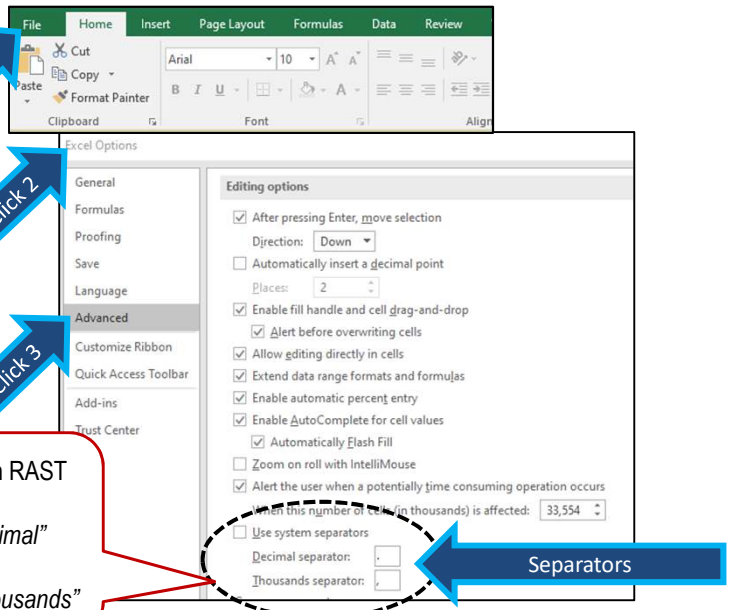
8

Separators
1.0 Period
or
1,0 Comma?

Click 1

Click 2

Click 3



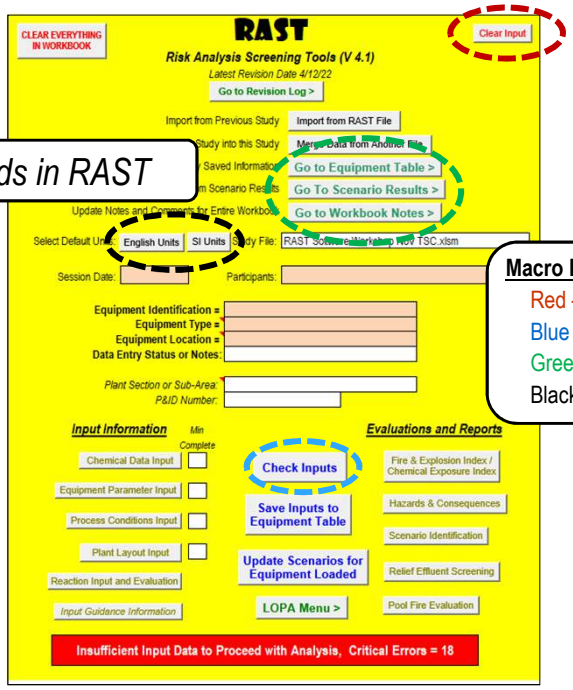
Separators

For Macros to work in RAST
Must use
1.0 *Period* for "Decimal"
Must use
1,000 *Comma* for "Thousands"

9

Main Menu Overview

Macro Commands in RAST



Macro Buttons
- Red – Clear Data
- Blue – Save or Check Data
- Green – Navigation
- Black – Execute Calculations

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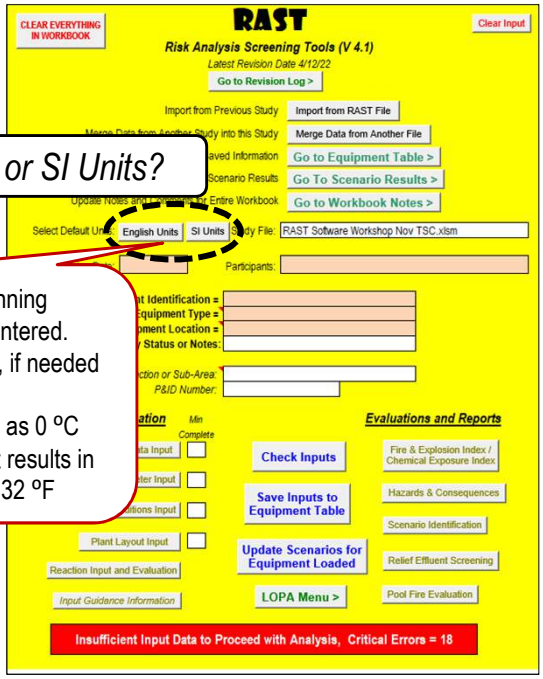
Main Menu Overview

English or SI Units?

Select Input Units at Beginning
Do not change once data entered.
Conversions made by software, if needed
Inputs do not change
Inputs in SI, 0 ºC will be read as 0 ºC
Changing to English after input results in software reading 0 ºF, ***not*** 32 ºF

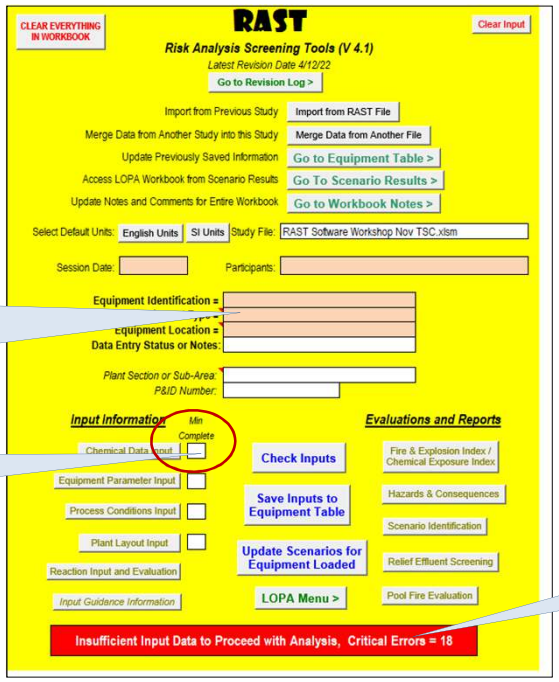


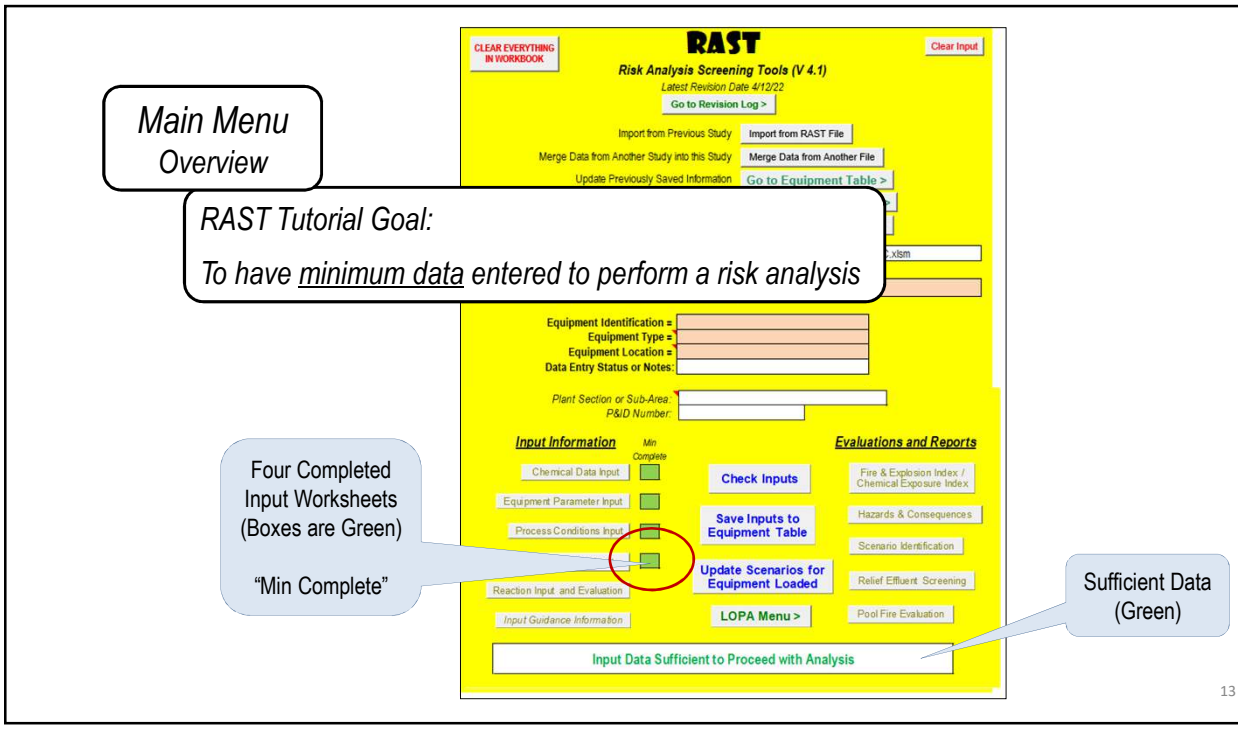
Main Menu Overview

Input Worksheets
Orange fields MUST have entries to satisfy "Min Complete"

Input Worksheet (Boxes are Clear)

Insufficient Data (Red)





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Case Study – Chlorine Release
DPC Process Description

Chlorine Repackaging facility

- DPC Enterprises, Festus, Missouri USA
- Repackages chlorine from rail cars to smaller containers

Chlorine Repackaging operations

- Connect chlorine rail cars to unloading station
- Transfer liquid chlorine through piping to filling station
- Clean and prepare empty cylinders and containers
- Fill 150 lb. (≈ 70 kg) cylinders and 1-ton (≈ 910 kg) containers

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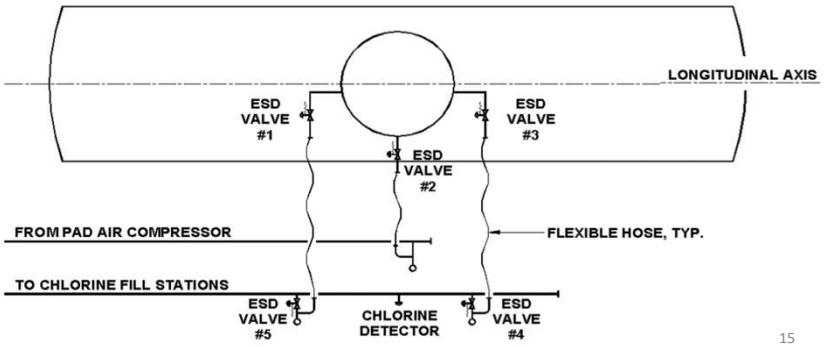
Case Study – Chlorine Release
Process Description

Unloading Station
- 3 Chlorine transfer hoses
  - 3.4 m (11 feet) long
  - 2.54 cm (1 inch) diameter

Hoses pressurized
- 8 bar (115 psig)



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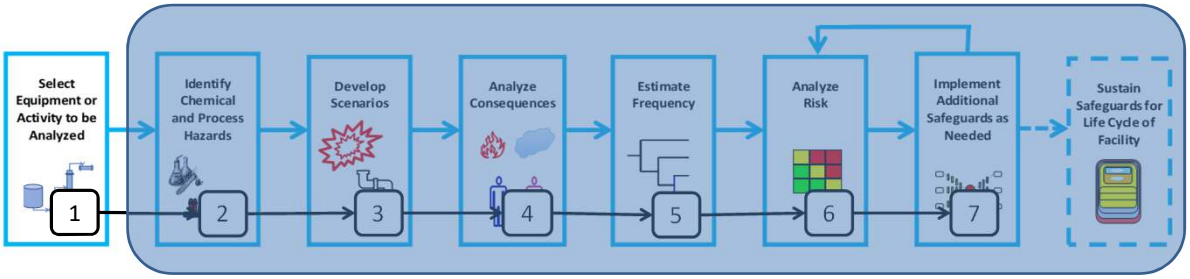
Step 1 – Identify Equipment



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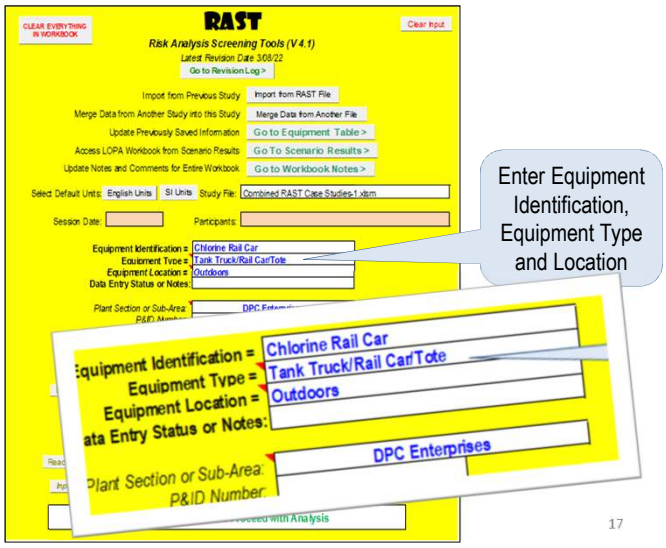
Case Study – Chlorine Release

Start by entering Chlorine Rail Car information

On the Main Menu

- Equipment Identification
  Text entry – **Chlorine Rail Car**
- Equipment type
  Drop down menu – **Tank Truck/Rail Car/Tote**
- Location
  Drop down menu – **Outdoors**



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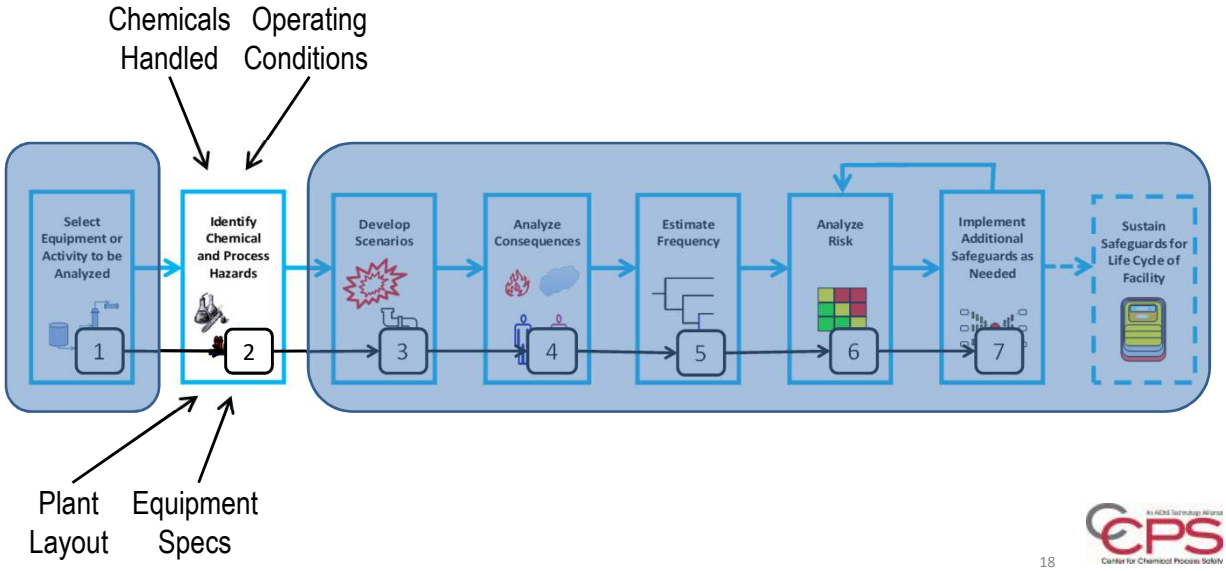
Step 2 – Identify Chemical and Process Hazards



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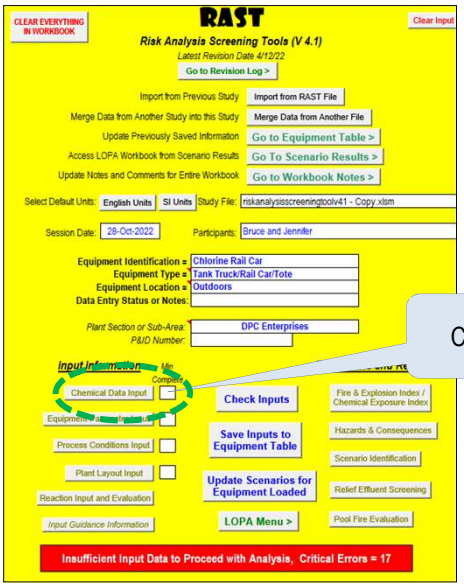
Case Study – Chlorine Release

Chemical Data Input



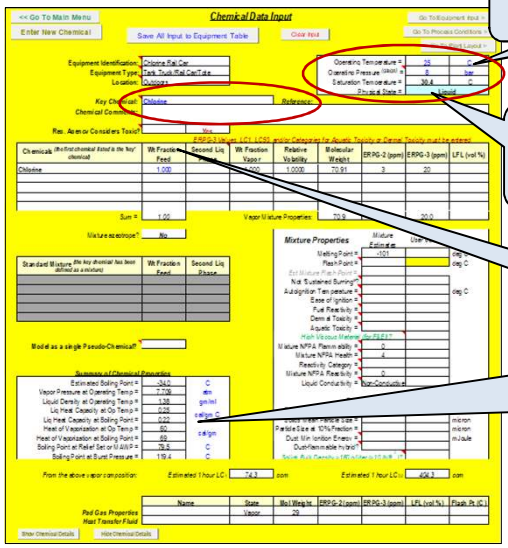
Case Study – Chlorine Release

Chemical Data Input

- Chlorine *(drop down menu)*
- Weight fraction is 1.0
- Operating
  Pressure 8 barg
  Temperature 25 ºC

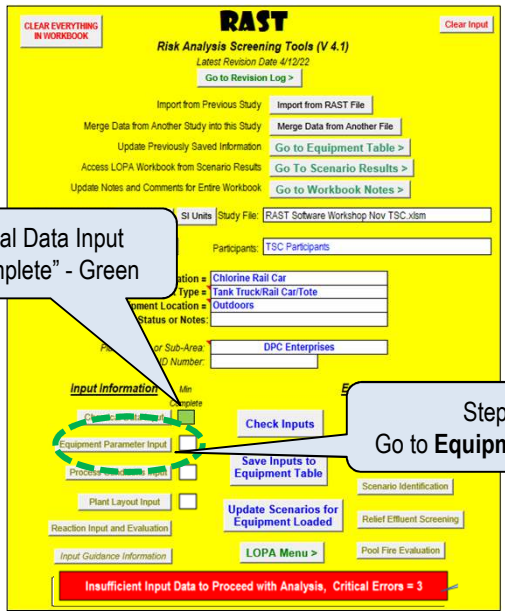
Note what happens if

- Operating data is
  Pressure 115 psig
  Temperature 77 ºF



Case Study – Chlorine Release

Main Menu

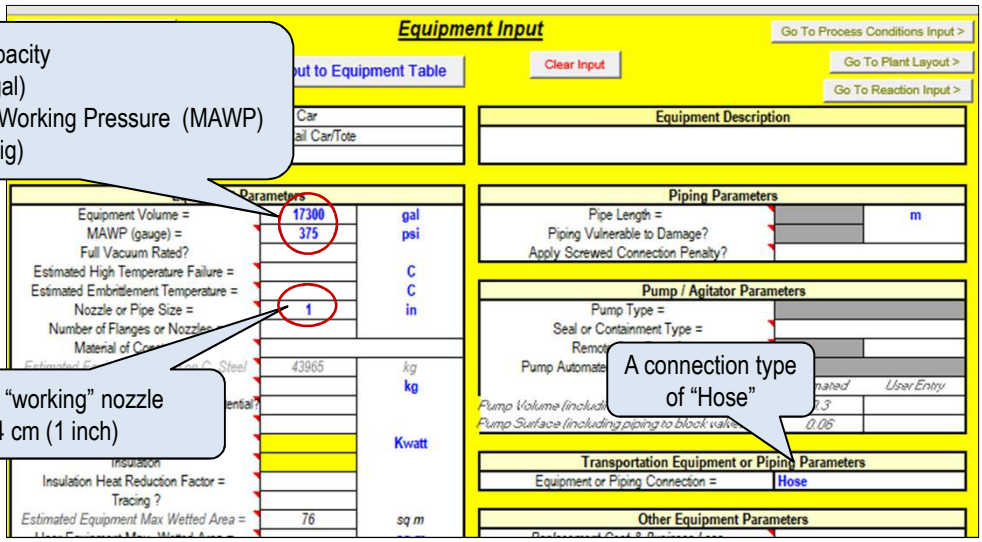


Chemical Data Input
"Min Complete" - Green

Step 2 Continued
Go to **Equipment Parameter Input**

Case Study – Chlorine Release

Equipment Input



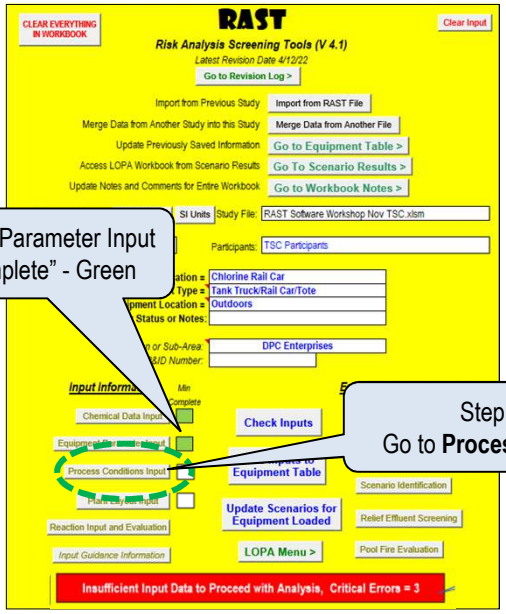
Chlorine Rail Car capacity
90 m^3 (17,300 gal)
Maximum Allowable Working Pressure (MAWP)
26 barg (375 psig)

A largest "working" nozzle
2.54 cm (1 inch)

A connection type
of "Hose"

Case Study – Chlorine Release

Main Menu

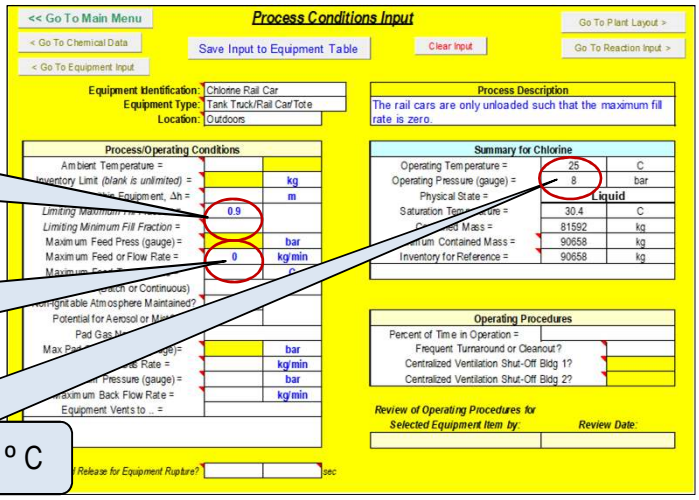


Equipment Parameter Input "Min Complete" - Green

Step 2 Continued
Go to **Process Conditions Input**

Case Study – Chlorine Release

Process Conditions Input

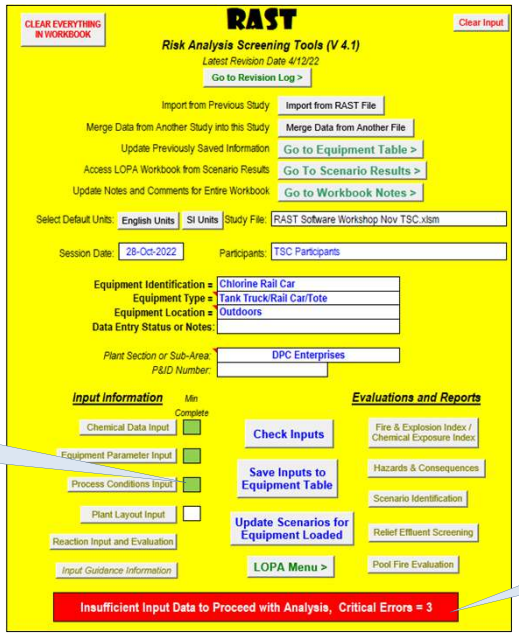


Rail Car received at 90% full
0.9 Maximum Fill Fraction
(Default 80% or 0.8)

Only a Rail Car unloading facility
Maximum flowrate to
Rail Car is zero (0)

Default Ambient Temperature 25 º C

Main Menu



Tutorial Check

Three Completed Input Worksheets (Boxes are Green)

Still Insufficient Data (Red)

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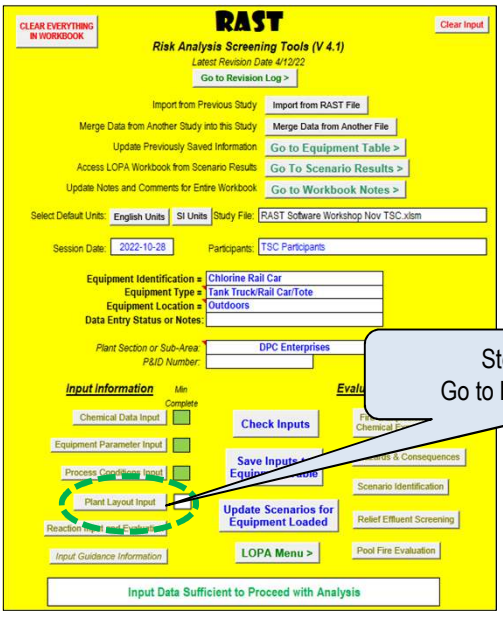
Case Study – Chlorine Release

Main Menu



Step 2 Continued
Go to **Plant Layout Input**

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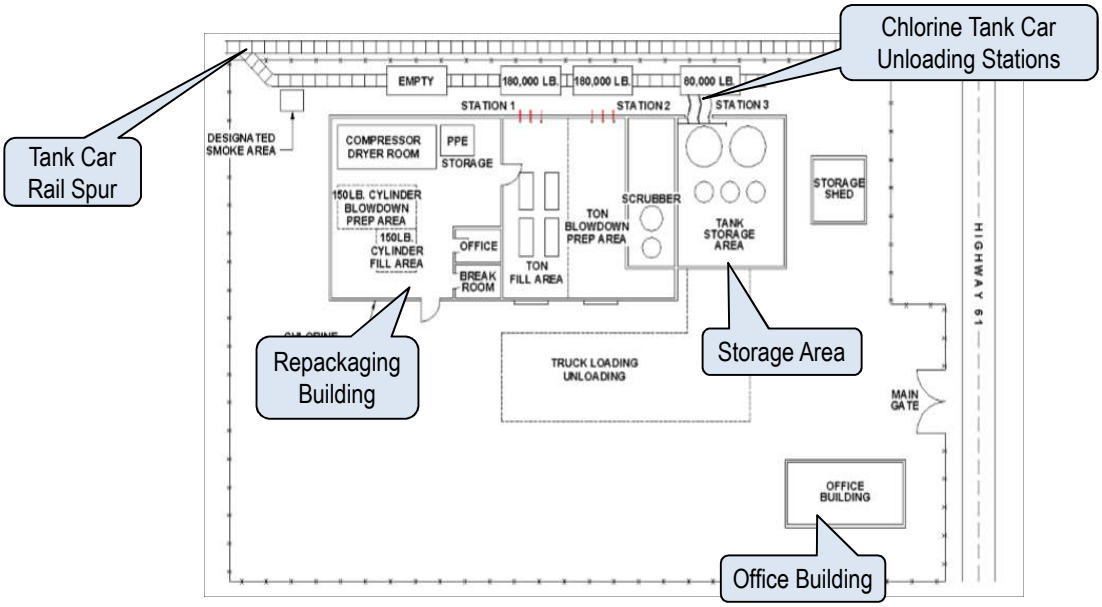
Case Study – Chlorine Release



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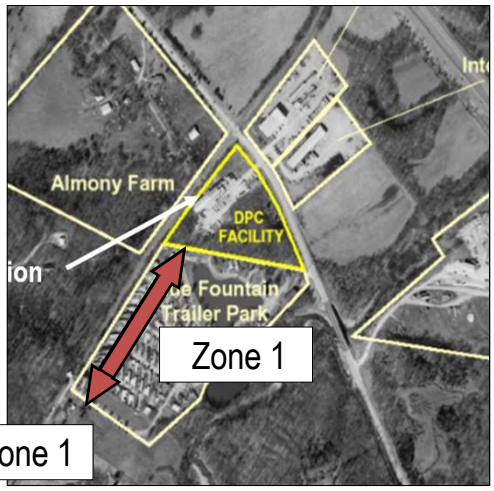
Case Study – Chlorine Release

Two offsite populated areas can be entered:

- Zone 1
  Begins at "Distance to Property Limit"
  To "Distance to End of Zone 1"

- Beyond Zone 1
  Begins at "Distance to End of Zone 1"



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Case Study – Chlorine Release

Examples of Sparsely populated areas

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

"Beyond Zone 1"

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

Examples of Moderately populated areas

1.5E-3 people/m^2
Typical suburban residential area

3E-3 people/m^2
Mobile Homes (upper end of Moderate)

"Zone 1"

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Case Study – Chlorine Release

Examples of Densely populated areas

4E-3 people/m^2
Very closely spaced single family dwellings

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

5E-3 people/m^2
Multifamily dwellings – multi-story apartments closely spaced

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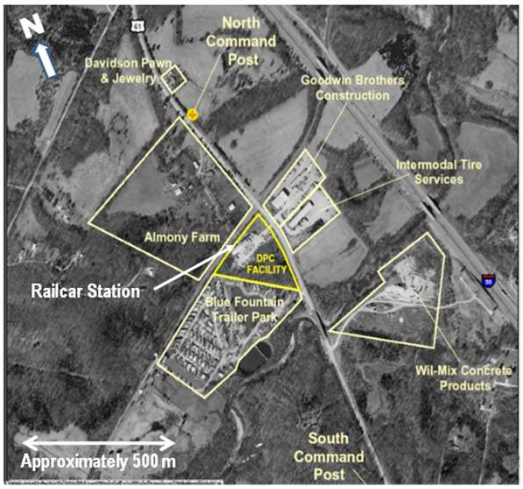
Case Study – Chlorine Release

Site office building 50 m (165 ft.) south of rail car station
~ 5 occupants

Blue Fountain residential mobile home park
("distance" to property limit)
100 m (330 ft.) southwest (~100 mobile homes)

Goodwin Brothers Construction and
Intermodal Tire Retreading
200 m (660 ft.) to east
15 full-time employees each (30 total)



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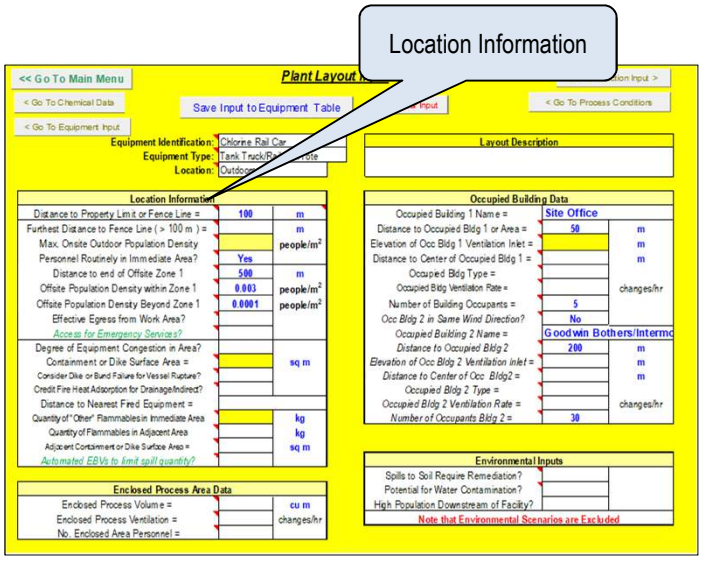
Case Study – Chlorine Release

Input Plant Layout Information

Location Information

<u>Zone 1</u>
The Blue Fountain mobile home park
- 100 m (330 ft.) to property line
- Extends to 500 m (1,650 ft.) from the rail car station (Zone 1)
- Population density 0.003 people/m^2

<u>Beyond Zone 1</u>
Beyond the mobile home park
- Rural
- Population density 0.0001 people/m^2



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Case Study – Chlorine Release

Input Plant Layout Information

Occupied Building 1

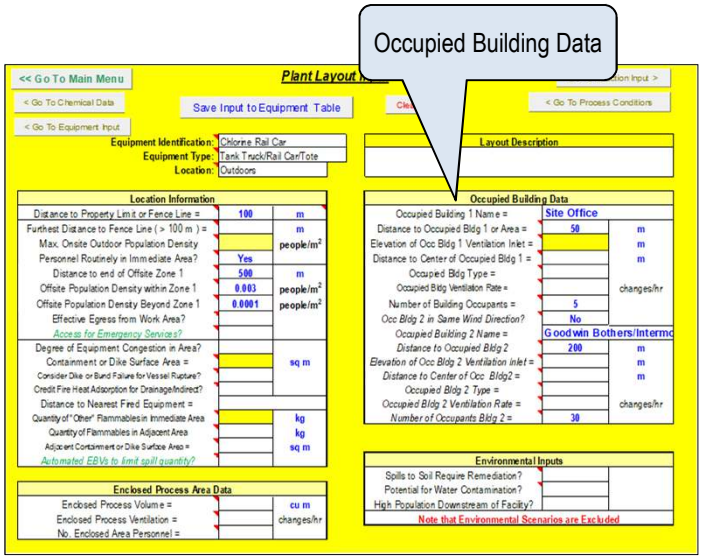
Site Office Building

- Distance 50 m (165 ft.)
- Number of Occupants 5

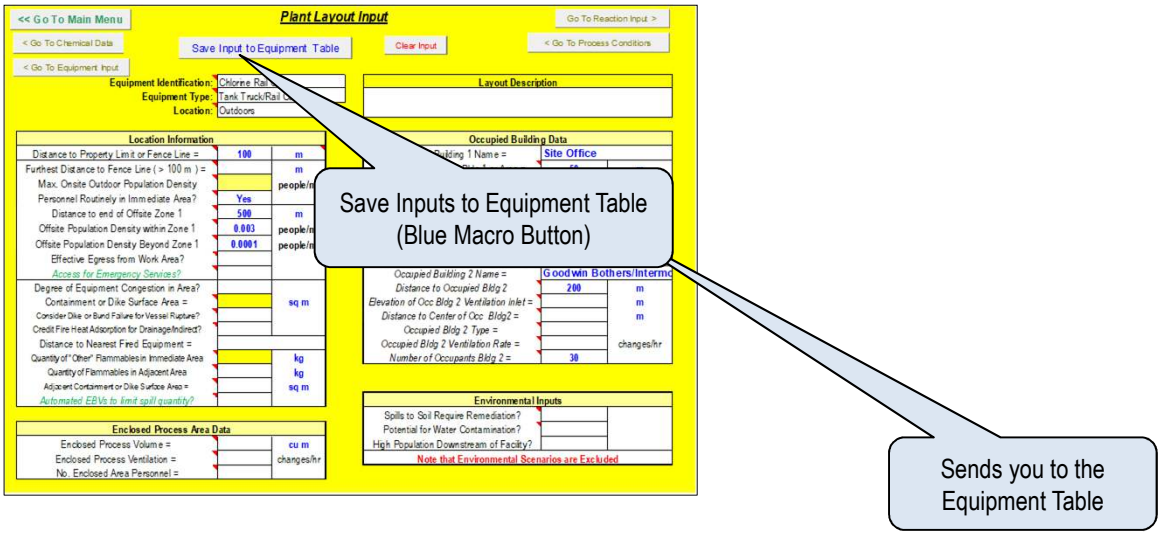
"Occupied Building" 2

Goodwin and Intermodal

- Distance 200 m (660 ft.)
- Number of Occupants 30

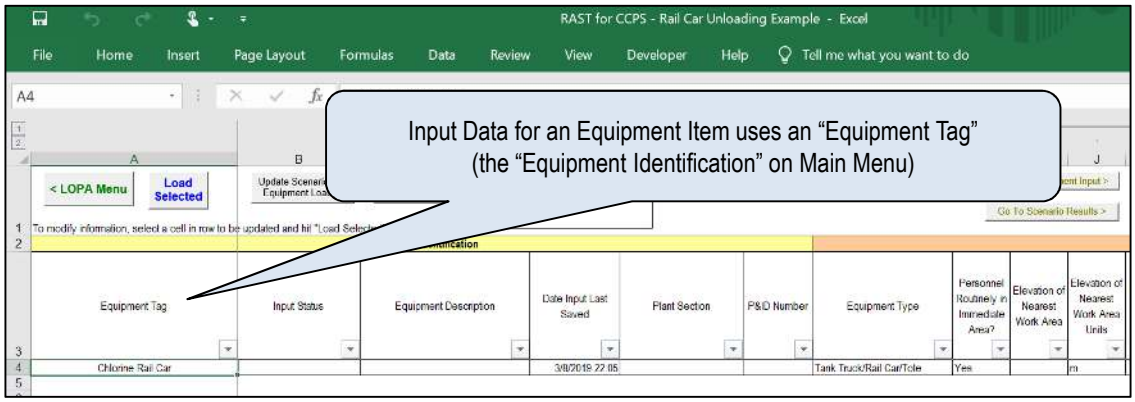


Case Study – Chlorine Release

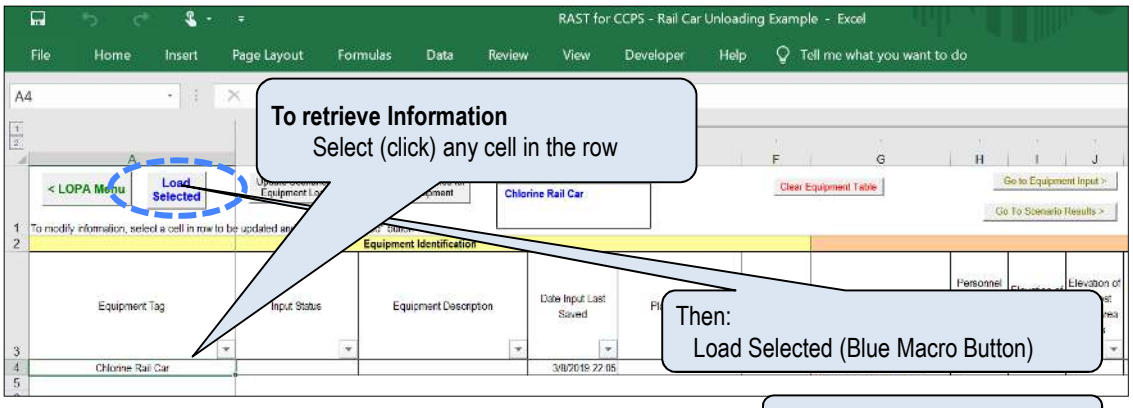


Case Study – Chlorine Release

Input stored in the Equipment Table
Single row contain the equipment information (only one entered for Tutorial)

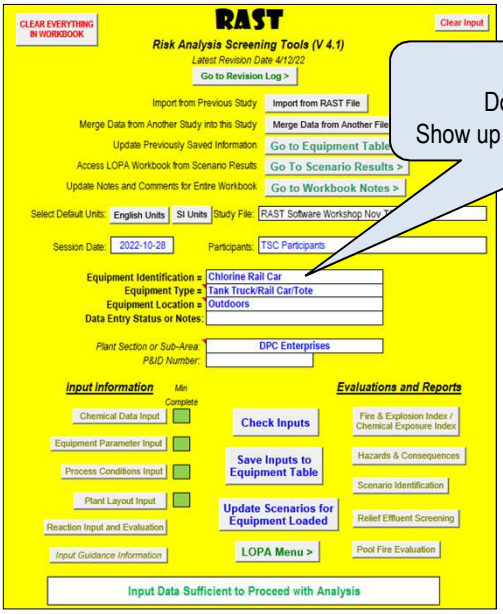


Case Study – Chlorine Release



Case Study – Chlorine Release

Main Menu



Tutorial Check:
Does "Chlorine Rail Car"
Show up in "Equipment Identification"?

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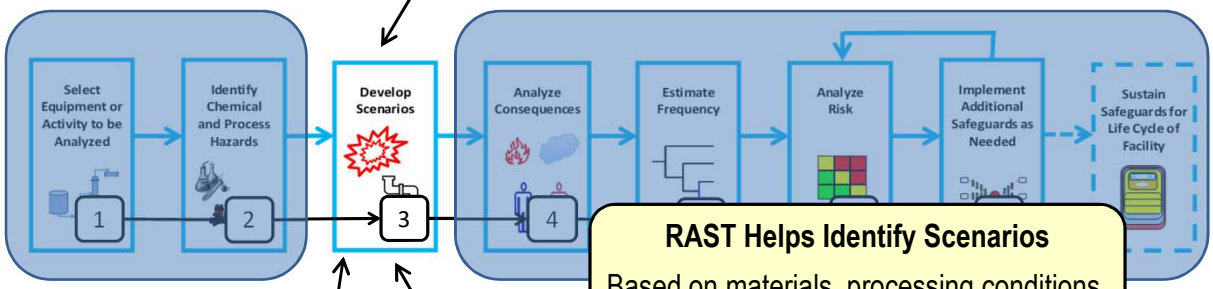
Step 3 – Develop Scenarios

Process Hazards Analysis (PHA)
Hazards and Operability Study (HAZOP)



RAST Helps Identify Scenarios

Based on materials, processing conditions and potential types of equipment failure

Historical Incidents

Equipment Integrity Failures

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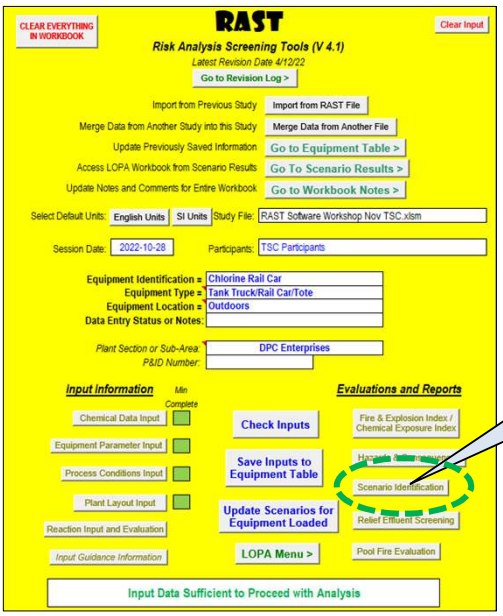
Case Study – Chlorine Release

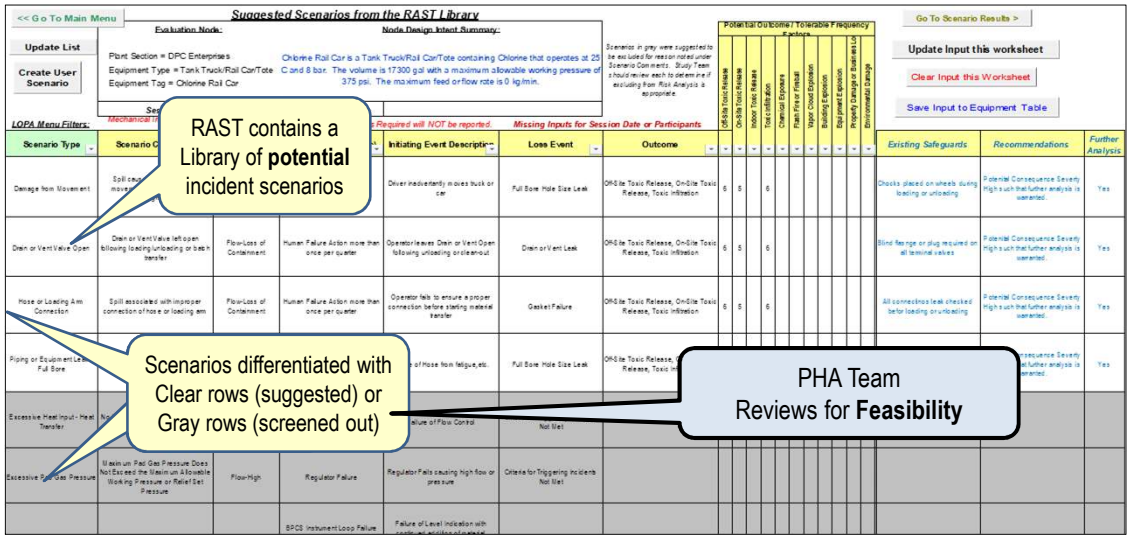
Main Menu



Step 3
Go to **Scenario Identification**

Case Study – Chlorine Release

Suggested Scenarios for Rail Car



RAST contains a Library of **potential** incident scenarios

Scenarios differentiated with Clear rows (suggested) or Gray rows (screened out)

PHA Team Reviews for **Feasibility**

Case Study – Chlorine Release

Suggested Scenarios for the Rail Car

Consult With Your Tutorial Neighbor:

1. **Review the suggested list of scenarios. Do these represent what you would expect for a rail car during unloading operation?**
2. **Are there scenarios that have been "screened out" (shown in gray) that should be considered?**
3. **Are there scenarios missing? (Possibly similar scenarios with different Initiating Events)**

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Case Study – Chlorine Release

Suggested Scenarios for the Rail Car

In an Actual HIRA, the next step for the PHA Team includes:

Identify additional scenarios using a hazards evaluation technique (such as HAZOP, What If/Checklist, etc.).

Enter the additional scenarios into RAST as a "User Scenario"

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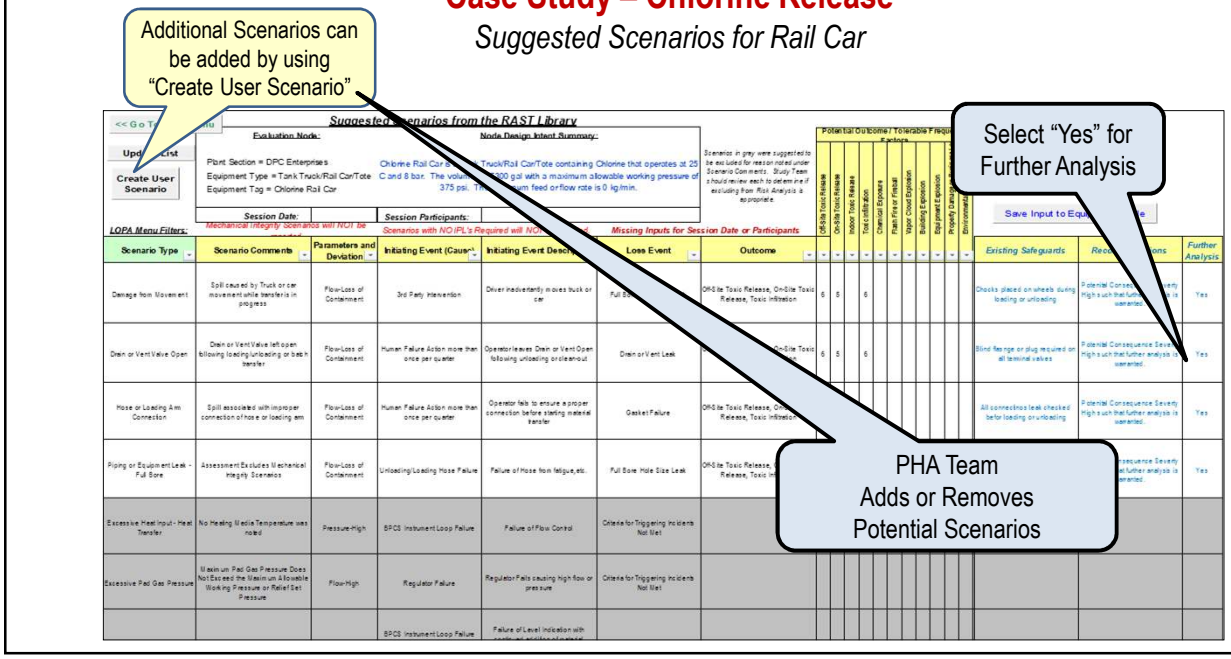
Case Study – Chlorine Release

Suggested Scenarios for Rail Car



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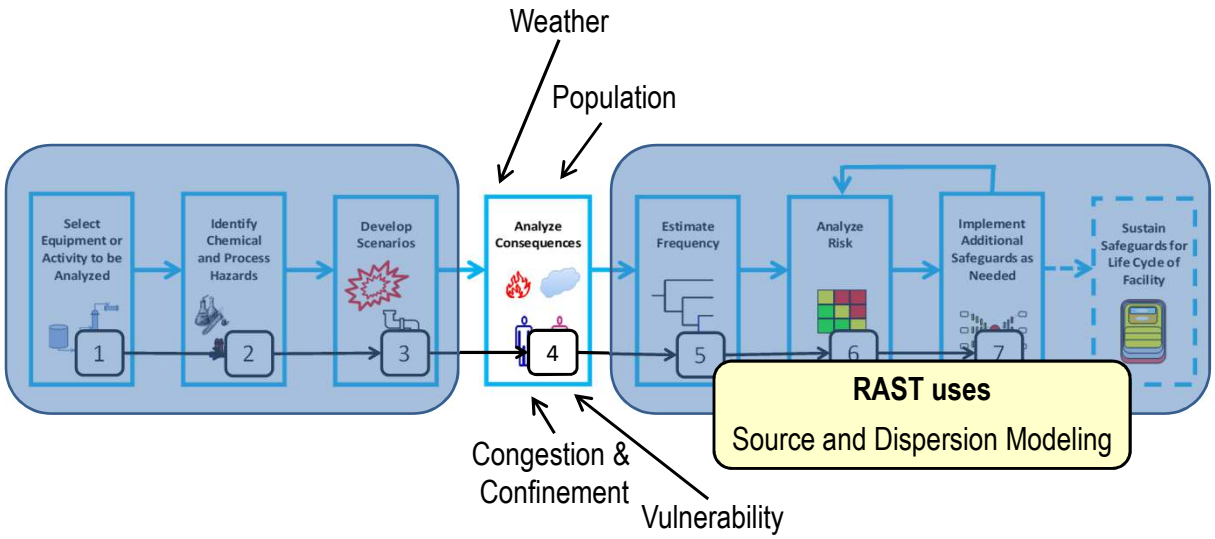
Step 4 – Analyze Consequences



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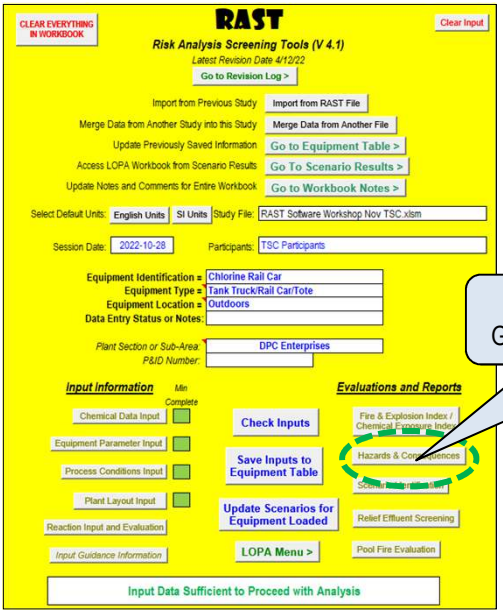
Case Study – Chlorine Release

Main Menu



Step 4
Go to **Hazards and Consequences**

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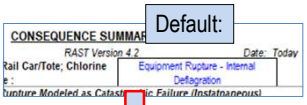
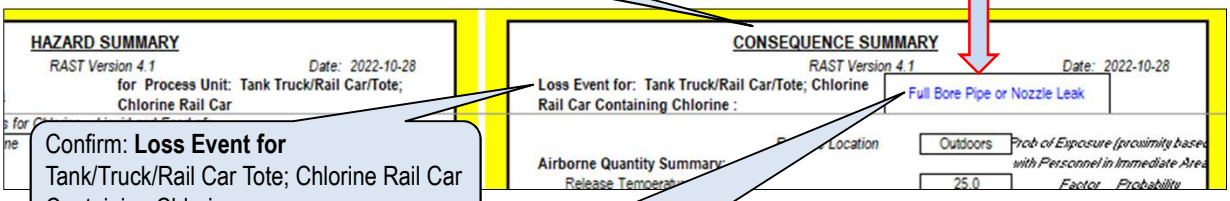
Case Study – Chlorine Release
Consequence Analysis

Scroll right to **CONSEQUENCE SUMMARY**

Default:





Confirm: **Loss Event for**
Tank/Truck/Rail Car Tote; Chlorine Rail Car Containing Chlorine

Select Scenario from dropdown menu:
Full Bore Pipe or Nozzle Leak

(the "worst" Consequence for a total hose failure)

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Case Study – Chlorine Release
Consequence Analysis

Scroll down to **Dispersion Summary** Section
- Default Atmospheric Stability D
- Default 3 m /sec wind speed
- ERPG-2 distance at 10 km (6.5 miles)

CONSEQUENCE SUMMARY

RAST Version 4.1 *Date: 2022-10-28*

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

Dispersion Summary (Atmospheric Stability Class D with 3 m/sec wind except as note

Max Distance to Time-Scaled ERPG-2, m	10375.0
Max Distance to Time-Scaled ERPG-3, m	3642.1
~~Max Distance to 1% Lethality for 1.5 F weather, m~~	~~1883.8~~
Max Distance to Estimated LC-50 Concentration, m	501.3
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	12635.5
Concentration at Distance to Unrestricted Work Area, ppm	1000000.0
Concentration within Occupied Bldg 1, ppm	17204.2
Concentration within Occupied Bldg 2, ppm	1765.8
Concentration within Enclosed Process Area, ppm	
Enclosed Process Area w/Ventilation, ppm	

Potential Toxic Impact within Occupied Building (Indoor Conc >

ERPG-1 - Temporary, non-disabling effects threshold.
ERPG-2 - Disabling (escape impairment) threshold
ERPG-3 - Life-threatening effects threshold

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Case Study – Chlorine Release
Consequence Analysis

Scroll down to **Incident Outcome** Section
- Offsite Toxic Impact potential: 80 people
- Building 1 Toxic Impact potential: 5 people
- Building 2 Toxic Impact potential: 27 people

CONSEQUENCE SUMMARY

RAST Version 4.1 *Date: 2022-10-28*

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

Incident Outcome and Consequence Summary:

	Exceeds Threshold	LOPA Tolerable Frequency Factors Estimated Number of People Impacted
Impact Assessment with Personnel routinely in the immediate area		
Offsite Toxic Impact based on Toxic Integration Method and 100 m to Fence Line with potential for 80.2 people	Yes	6
Onsite Toxic Impact based on Distance to LC-50 Concentrat	Yes	6
Outdoor Toxic Exposure Duration 600 sec		
Onsite Flash Fire Impact based on Distance to 0.5 LFL Concentration of 0 m		NA
Chemical Exposure based on Dermal or Thermal Hazards and Spray Distance of 14		NA
Equipment Rupture Direct Blast Impact based on Distance tc		
Onsite Thermal Radation Impact based on Distance from Fireball		
Number of Potential Severe Toxic Impacts Onsite: 15.8 people		
Number of Potential Severe Flash Fire/Fireball Impacts Onsite: 0 people		
Occupied Building Toxic Impact	Yes	6
Number of Potential Severe Impacts for Building 1: 5 people		
Number of Potential Severe Impacts for Building 2: 26.7 people		
Occupied Building Impact from Vapor Cloud Explosion	No	NA
Number of Potential Severe Impacts for Building 1: 0 people and 0 offsite		
Number of Potential Severe Impacts for Building 2: 0 people and 0 offsite		
Occupied Building Rupture Explosion Impact	No	
Number of Potential Severe Impacts for Building 1: 0 people and 0 offsite		
Number of Potential Severe Impacts for Building 2: 0 people and 0 offsite		
Environmental Impact:		NA

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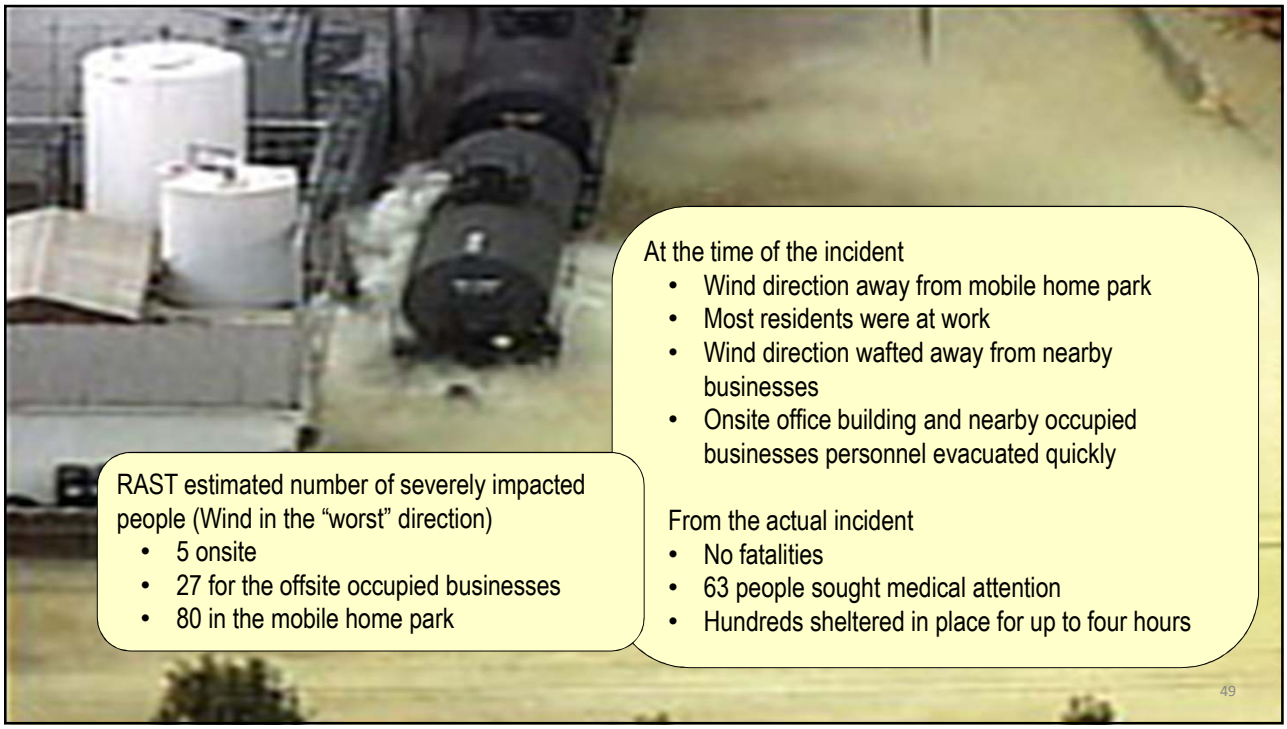

RAST estimated number of severely impacted people (Wind in the "worst" direction)

- 5 onsite
- 27 for the offsite occupied businesses
- 80 in the mobile home park

At the time of the incident

- Wind direction away from mobile home park
- Most residents were at work
- Wind direction wafted away from nearby businesses
- Onsite office building and nearby occupied businesses personnel evacuated quickly

From the actual incident

- No fatalities
- 63 people sought medical attention
- Hundreds sheltered in place for up to four hours

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Case Study – Chlorine Release
Consequence Analysis

<u>At time incident *(changed RAST Defaults)*</u>

- Vapor release rate of 2 kg/sec *due to flow restrictor*
- Actual 2 m/sec wind speed
- ERPG-2 distance is estimated at 7.2 km (4.5 miles)

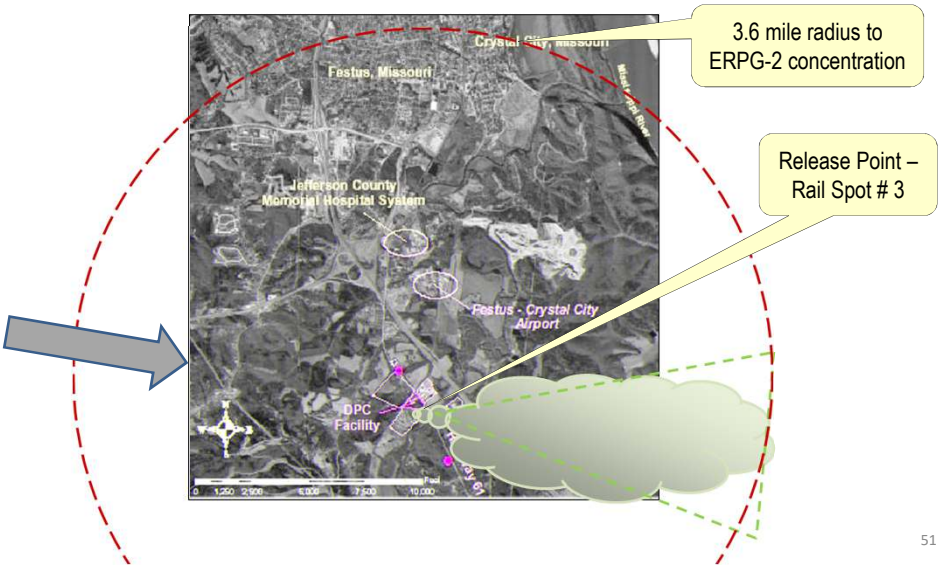
<u>Considering assumptions, "good" agreement with CSB</u>

- Vapor release rate: 2 kg/sec
- 2 m /sec wind speed
- ERPG-2 distance is estimated at 6 km (3.6 miles)

50

Case Study – Chlorine Release
Consequence Analysis

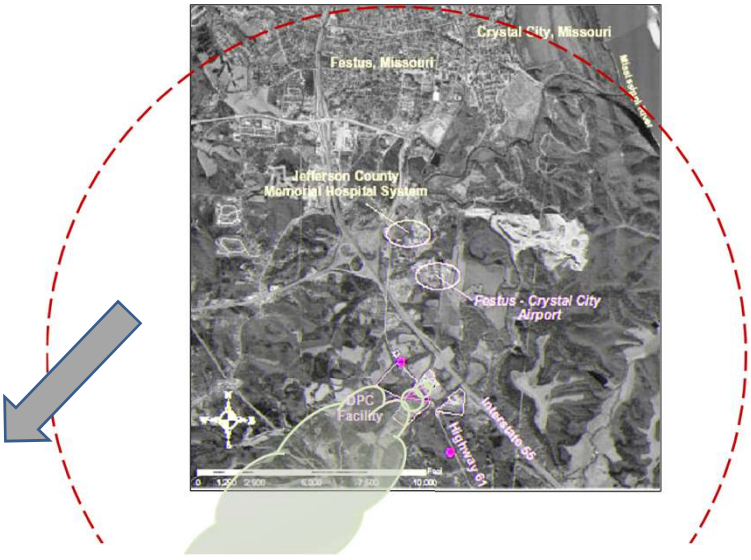
Actual Wind Direction of Incident



51

Case Study – Chlorine Release
Consequence Analysis

"Worst" Wind Direction Used in RAST



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Case Study – Chlorine Release
Consequence Analysis

RAST selects wind direction toward the highest population (a "worst" case)

Risk Analysis assumption

The wind direction is unknown

1) Southwest toward the mobile home park
2) Directly toward the nearby businesses

Actual incident conditions

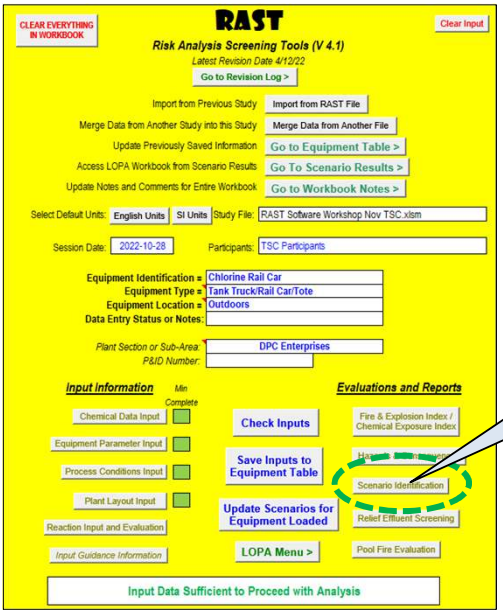
The wind direction is known

Toward the east-southeast

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

Case Study – Chlorine Release

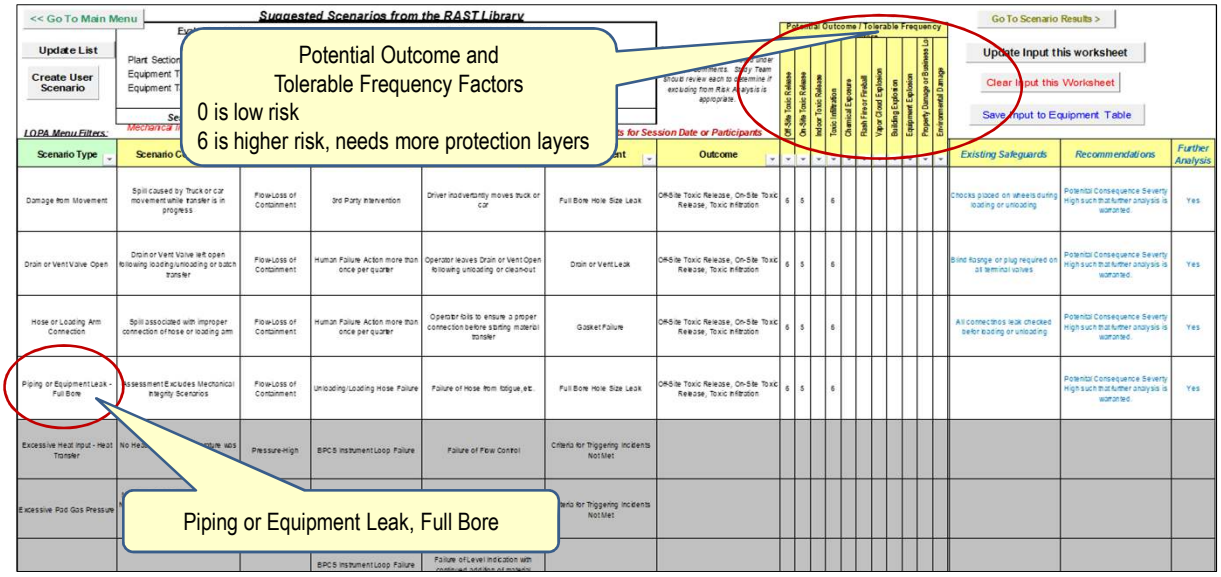
Main Menu



Go to **Scenario Identification**

Case Study – Chlorine Release

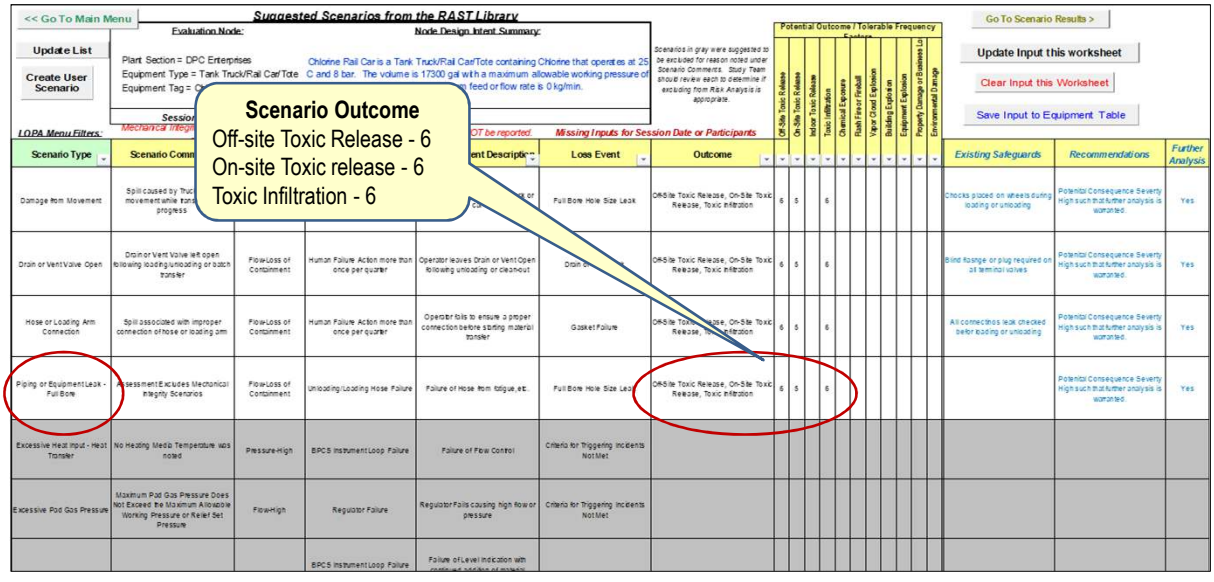
Suggested Scenarios for Rail Car



55

Case Study – Chlorine Release

Suggested Scenarios for Rail Car



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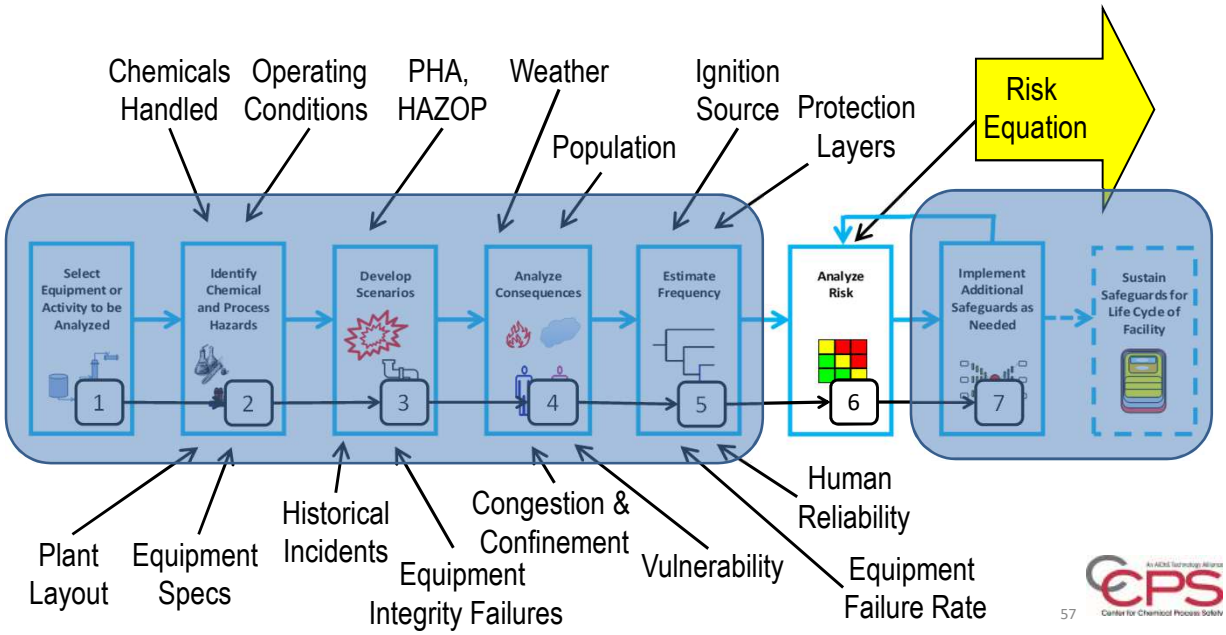
Step 6 – Analyze Risk



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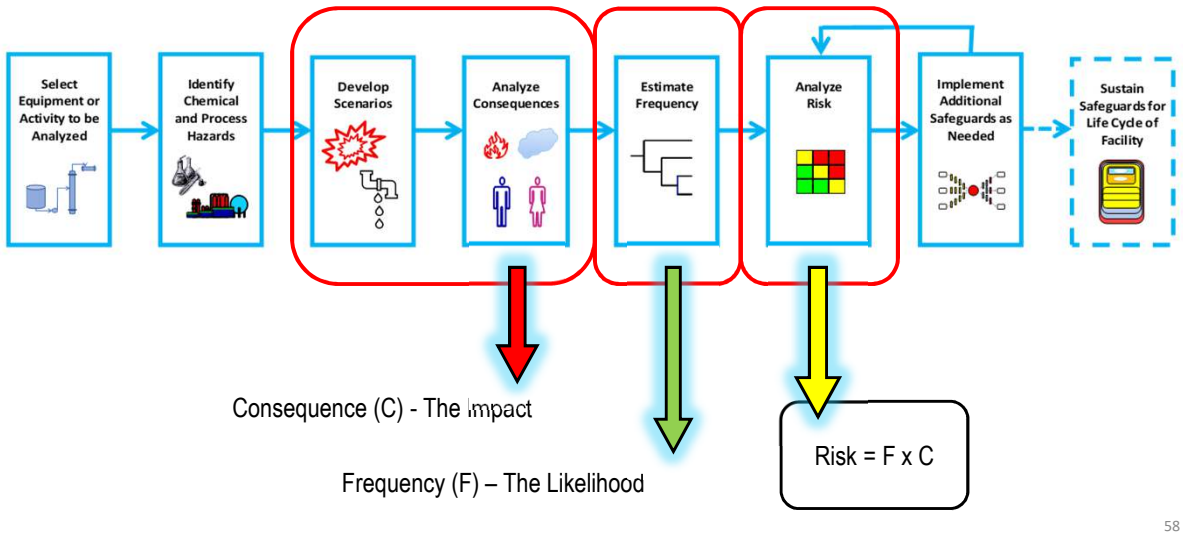
Risk Screening Estimates using RAST



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Risk Analysis Screening Tool (RAST)
Case Study – Chlorine Release

Takeaway:

A risk analysis anticipates the event
An incident investigation uses information *from the event*

RAST

Suggested a hose failure as one of many scenarios
Recognized that an off-site toxic impact could be feasible
Estimated a conservative number of people severely impacted

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Risk Analysis Screening Tool (RAST)
Case Study – Chlorine Release

A key question is "Could the outcome of the chlorine release been much worse had the wind conditions been different?"

60

Did we meet our goal?

Use an Incident Case Study to show decisions a Process Hazards Analysis (PHA) Team can make when using the RAST software during their review

Other Questions?

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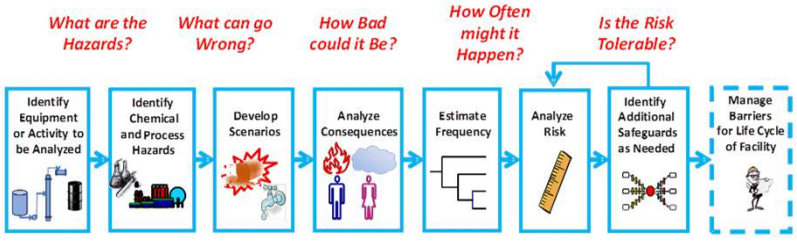
Risk Analysis Screening Tools (RAST)

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.

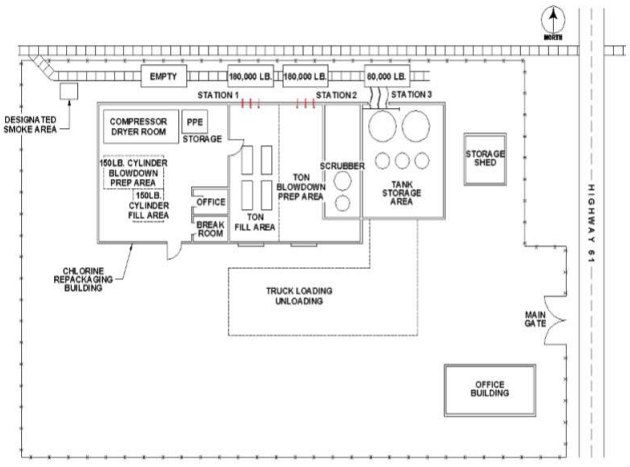
Risk Analysis Screening Tools (RAST) Overview / Demonstration

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.

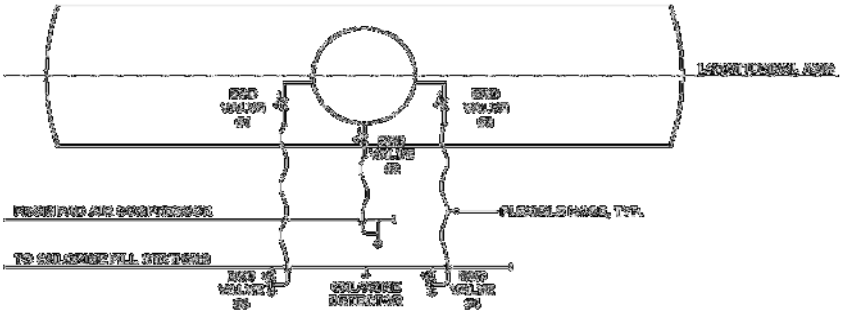
Pad air is used to help push the liquid chlorine out of the tank car into the plant piping. An eduction pipe is used to unload liquid material. It is a long steel pipe attached to the liquid valve and extends to the bottom of the tank car.



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.

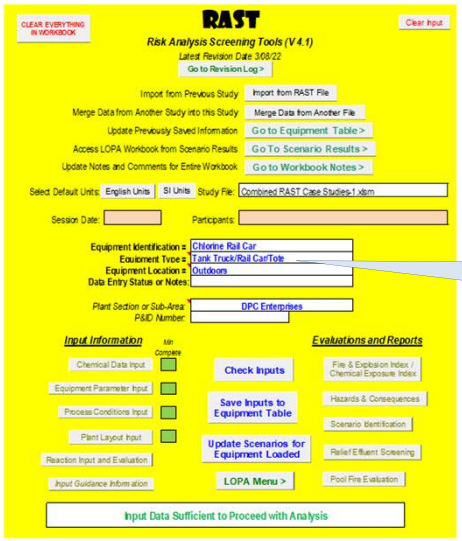
One the Main Menu, enter the equipment identification as the **Chlorine Rail Car**, equipment type as **Tank Truck/Rail Car/Tote** and location as **Outdoors**.

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.



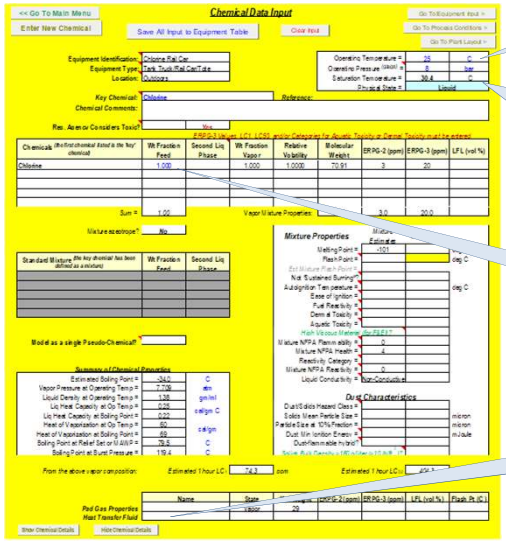
Enter Equipment Identification, Equipment Type and Location

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"

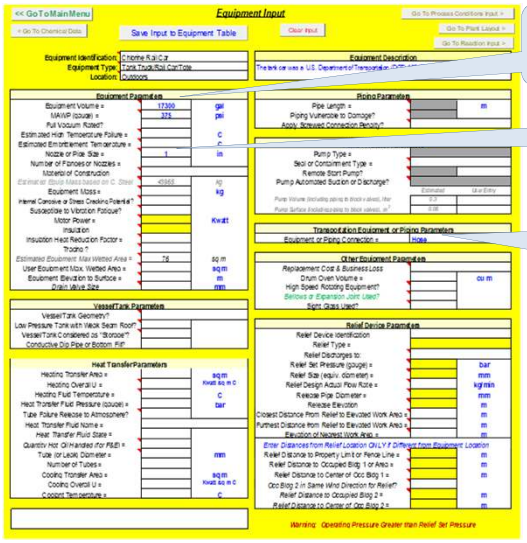
RAST allows up to 5 components.

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.

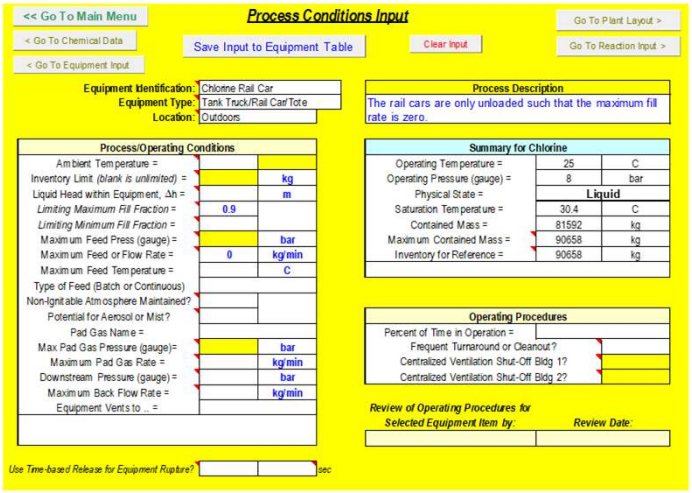
Case Study – Chlorine Repackaging

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).

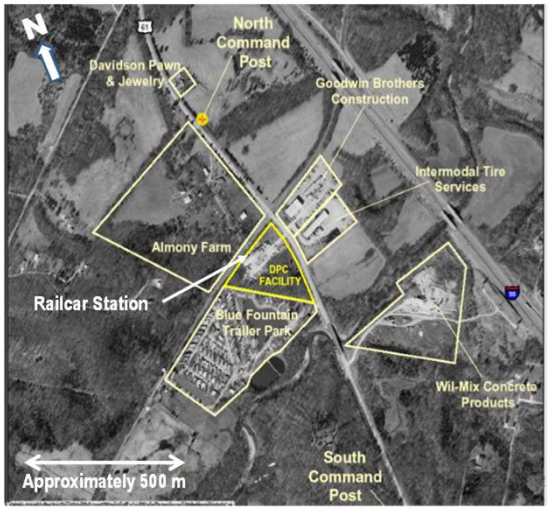


Case Study – Chlorine Repackaging

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

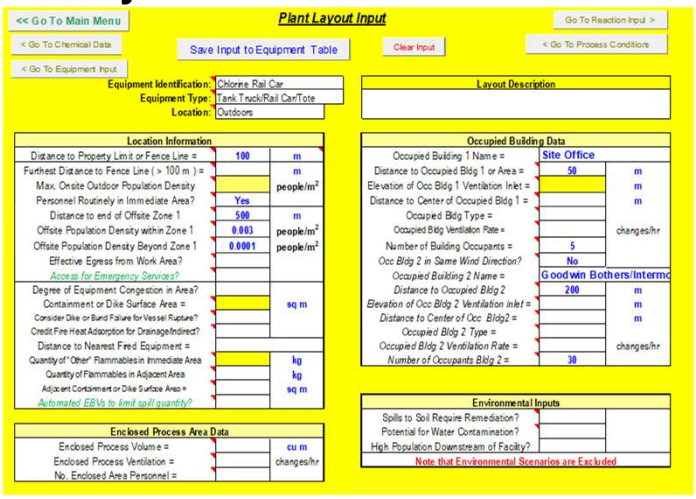
4E-3 people/m²
Multifamily dwellings – 2 story apartments and duplexes

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).

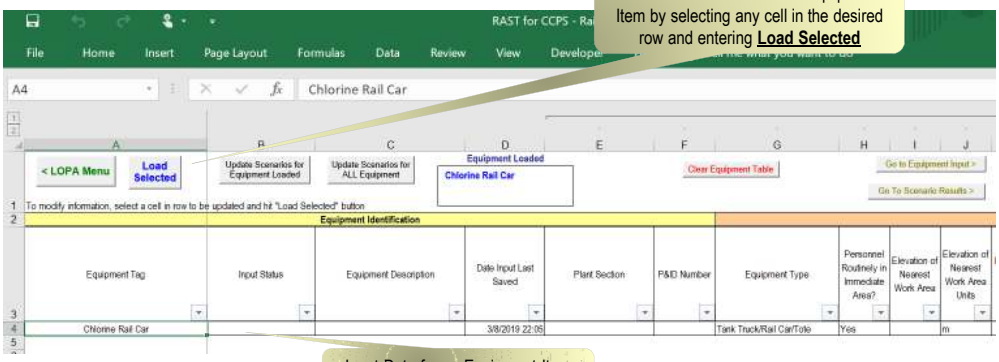
The site office and offsite businesses are entered as occupied buildings.



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.



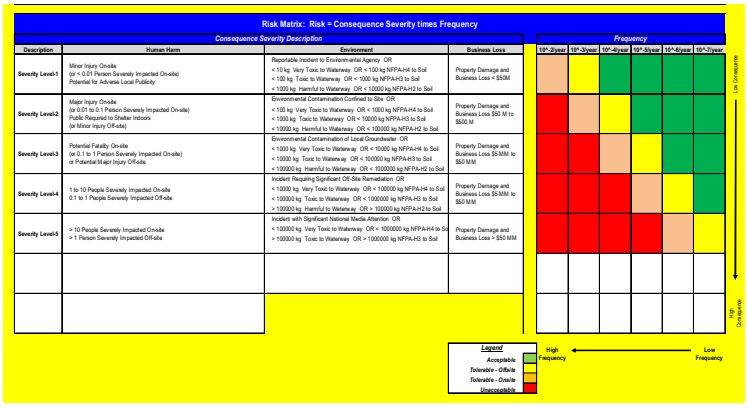
Risk Analysis Screening Tools (RAST) Overview / Demonstration

Risk Analysis Screening Tools (RAST)

Risk Matrix

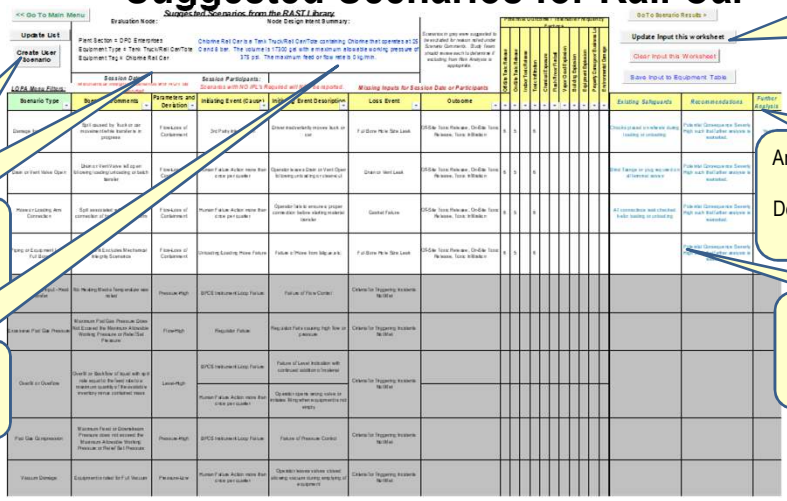
To understand the Consequence Severity and Tolerable Frequency, the values for key Study Parameters and a Risk Matrix may be viewed on the Workbook Notes worksheet. These values may be updated on hidden worksheets and should reflect the company's specific risk criteria.

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

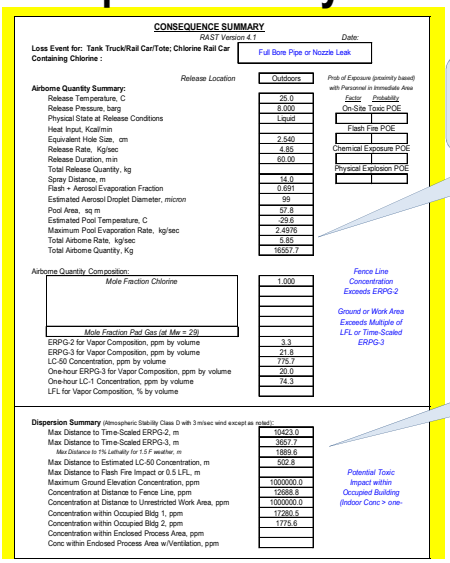
WORKING WITH YOUR EVALUATION TEAM:

- ❑ **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..

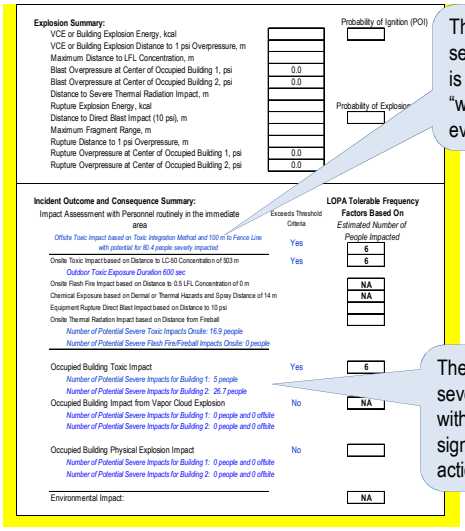
The actual wind speed was nearly 2 m/sec. Wind speed, atmospheric stability, and surface roughness are Administrative Parameters that may be adjusted on hidden worksheets.

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

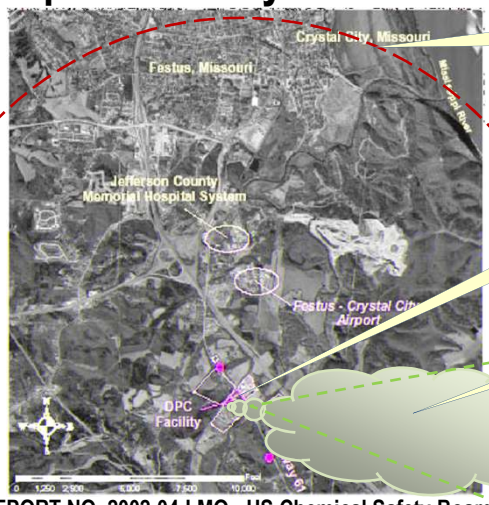
Case Study – Chlorine Repackaging

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

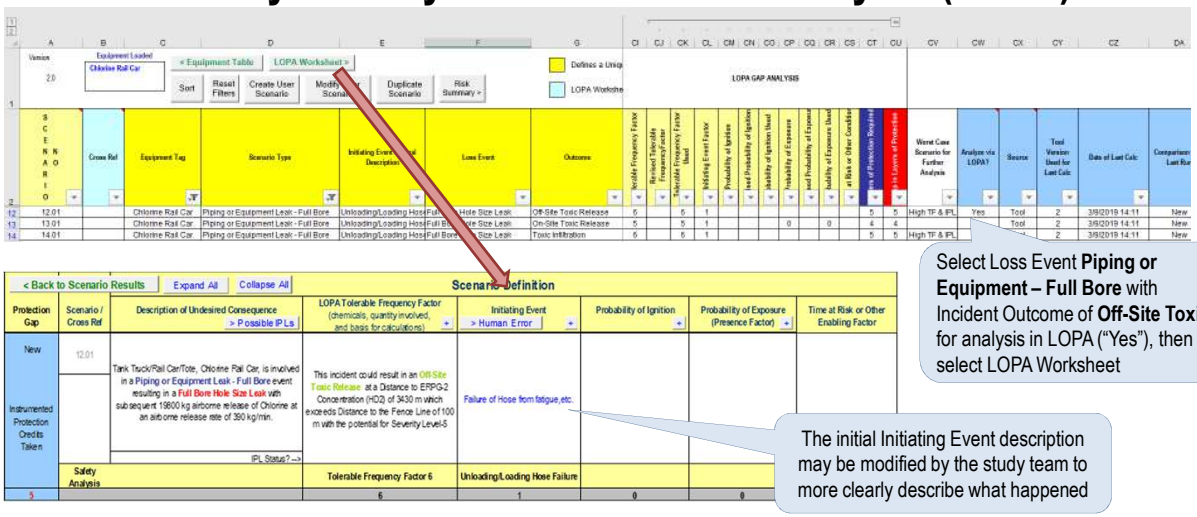
Estimated Cloud plume in RAST

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.

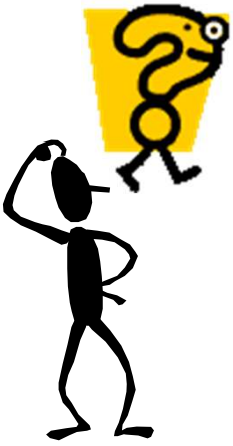
Risk Analysis Screening Tools (RAST)

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?



Purdue Process Safety and Assurance Center (P2SAC) Spring 2023 Conference
May 8, 2023

Tutorial on the "Risk Analysis Screening Tool (RAST)"

The Risk Analysis Screening Tool (RAST) can be used to estimate the risk of a scenario, such as a scenario that is proposed during a Process Hazards Analysis (PHA). The RAST software uses the Hazard Identification and Risk Analysis (HIRA) approach to identify the hazards, propose loss of containment scenarios, estimate the potential impact, estimate the potential frequency, and then evaluate the risk of the scenario.

The purpose of the tutorial is to have each person use RAST on a case study of a loss of containment incident to better understand what information is needed and where this information is entered into the software.

Each participant must download the RAST software (Version 4.2, Issued February 15, 2023) on to their laptop before the session.
https://www.aiche.org/ccps/resources/tools/risk-analysis-screening-tool-rast-and-chemical-hazard-engineering-fundamentals-chef/download-and-install

We will be using the 5th Case Study: *Chlorine Release DPC Enterprises*.
https://www.aiche.org/ccps/resources/tools/risk-analysis-screening-tool-rast-and-chemical-hazard-engineering-fundamentals-chef/case-studies

References include:

1) The *RAST User Manual V4.2*
https://www.aiche.org/ccps/resources/tools/risk-analysis-screening-tool-rast-and-chemical-hazard-engineering-fundamentals-chef/rast-user-and-chef-manuals

2) The US Chemical Safety and Hazards Investigation Board (CSB) report on the Chlorine release in Festus, Missouri US (*DPC Enterprises Festus Chlorine Release 2003*)
https://www.csb.gov/dpc-enterprises-festus-chlorine-release/
   A news station's helicopter view of the release can be seen in the CSB's *Emergency Preparedness* video (Festus images from 7:10 to 8:08; on YouTube)
   https://www.youtube.com/watch?v=R2Ez7lkjg1Y&t=429s

The Steps in The Risk Analysis Screening Tool (RAST)