



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

*DPC Enterprises
Festus, Missouri USA
August 2002*

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Purdue Process Safety and Assurance Center (P2SAC)
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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

RAST Tutorial Outline

Background

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

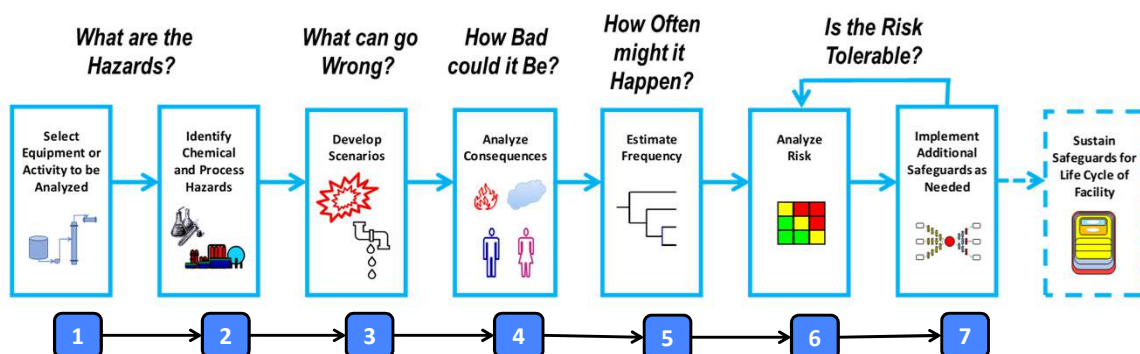
Incident Case Study – Chlorine Release

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

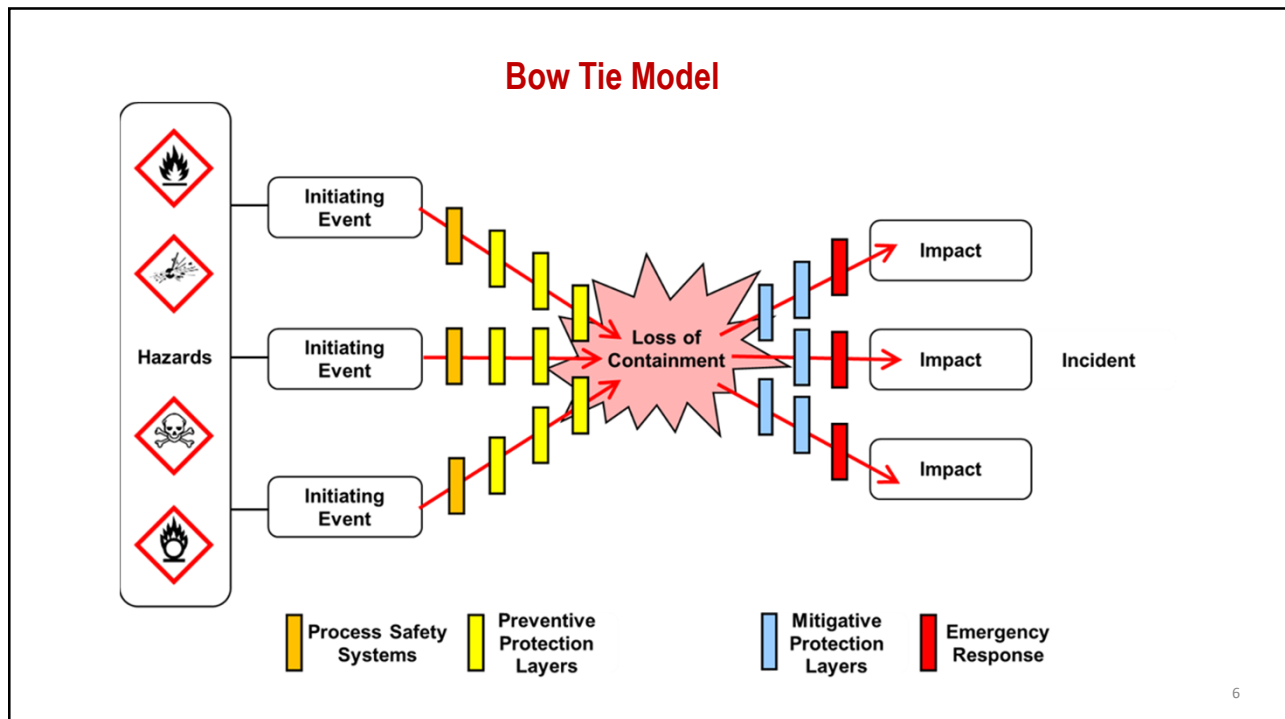
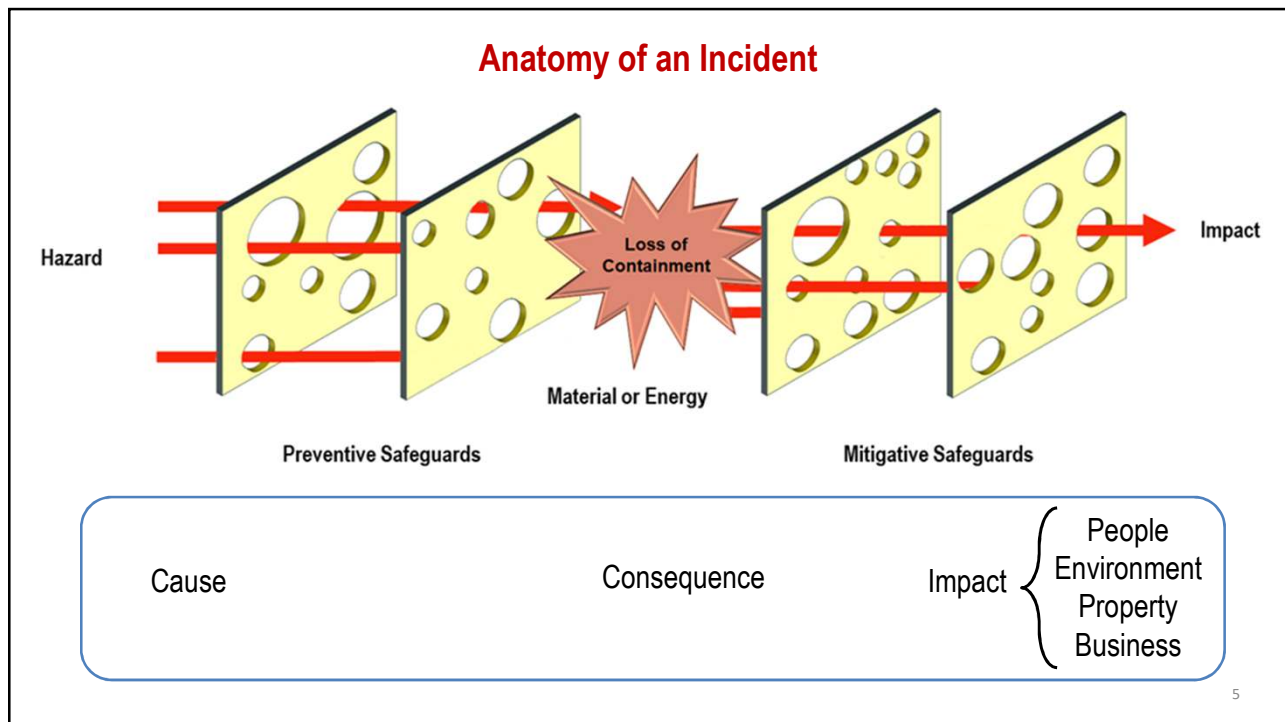
3

Hazard Identification and Risk Analysis (HIRA)

Five Questions and Seven Steps



4



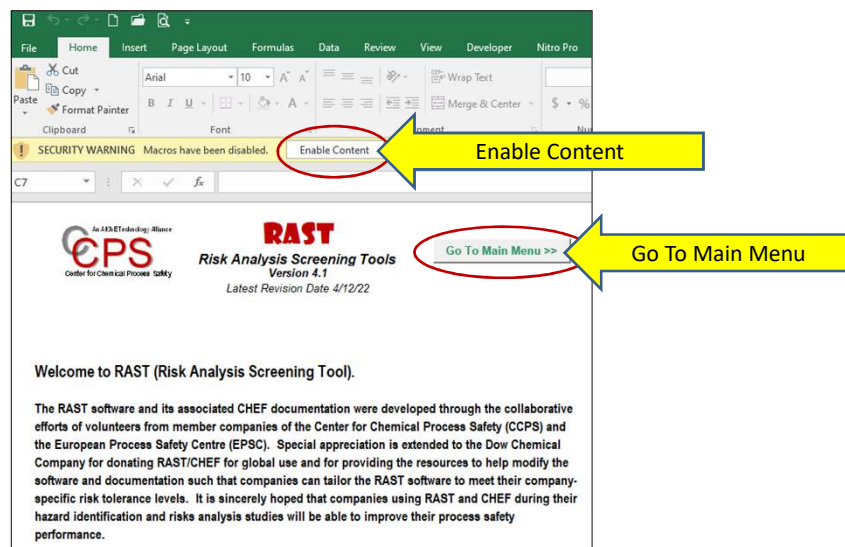
Risk Analysis Screening Tool (RAST)

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



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Separators
1.0 *Period*
or
1,0 *Comma*?

Click 1

Click 2

Click 3

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

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Main Menu Overview

Macro Commands in RAST

Macro Buttons

Red – Clear Data

Blue – Save or Check Data

Green – Navigation

Black – Execute Calculations

10

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 °C will be read as 0 °C
 Changing to English after input results in
 software reading 0 °F, **not** 32 °F

RAST Risk Analysis Screening Tools (V 4.1)
 Latest Revision Date 4/12/22
 Go to Revision Log >

Import from Previous Study | Import from RAST File
 Merge Data from Another Study into this Study | Merge Data from Another File
 Go to Equipment Table >
 Go To Scenario Results >
 Go to Workbook Notes >

Select Default Units: **English Units** | SI Units | Study File: RAST Software Workshop Nov TSC.xism

Participants: _____

Equipment Identification = _____
 Equipment Type = _____
 Equipment Location = _____
 Status or Notes: _____

Location or Sub-Area: _____
 P&ID Number: _____

Evaluations and Reports

Fire & Explosion Index / Chemical Exposure Index
 Hazards & Consequences
 Scenario Identification
 Relief Effluent Screening
 Pool Fire Evaluation

Check Inputs
Save Inputs to Equipment Table
Update Scenarios for Equipment Loaded
LOPA Menu >

Insufficient Input Data to Proceed with Analysis, Critical Errors = 18

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date 4/12/22
[Go to Revision Log >](#)

[CLEAR EVERYTHING IN WORKBOOK](#) [Clear Input](#)

Import from Previous Study [Import from RAST File](#)
Merge Data from Another Study into this Study [Merge Data from Another File](#)
Update Previously Saved Information [Go to Equipment Table >](#)
Access LOPA Workbook from Scenario Results [Go To Scenario Results >](#)
Update Notes and Comments for Entire Workbook [Go to Workbook Notes >](#)

Select Default Units: [English Units](#) [SI Units](#) Study File: [RAST Software Workshop Nov TSC.xism](#)

Session Date: Participants:

Equipment Identification =
Equipment Location =
Data Entry Status or Notes:

Plant Section or Sub-Area:
P&ID Number:

Input Information Min Complete Evaluations and Reports

Chemical Data Input [Check Inputs](#) [Fire & Explosion Index / Chemical Exposure Index](#)
Equipment Parameter Input [Save Inputs to Equipment Table](#) [Hazards & Consequences](#)
Process Conditions Input [Update Scenarios for Equipment Loaded](#) [Scenario Identification](#)
Plant Layout Input [LOPA Menu >](#) [Relief Effluent Screening](#)
Reaction Input and Evaluation [Input Guidance Information](#) [Pool Fire Evaluation](#)

Insufficient Input Data to Proceed with Analysis, Critical Errors = 18

**Main Menu
Overview**

RAST Tutorial Goal:
To have minimum data entered to perform a risk analysis

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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

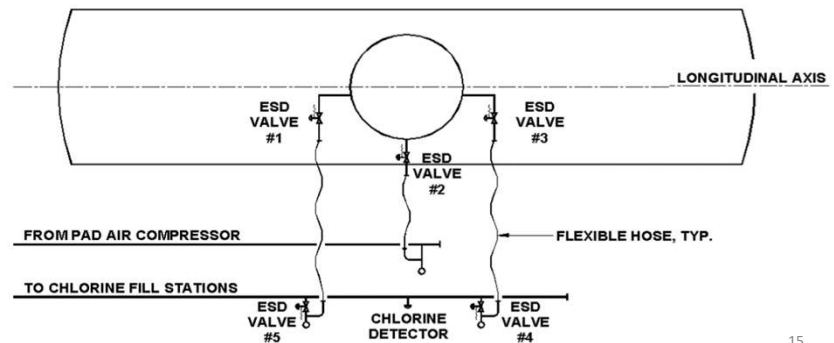
Case Study – Chlorine Release Process Description

Unloading Station

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

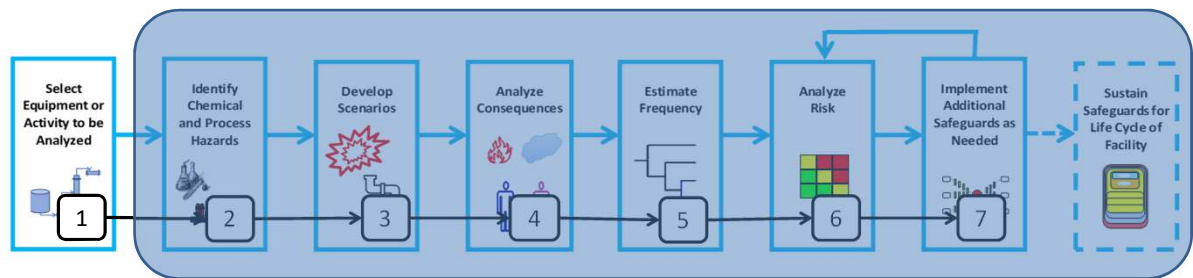
Hoses pressurized

8 bar (115 psig)



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Step 1 – Identify Equipment



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Case Study – Chlorine Release

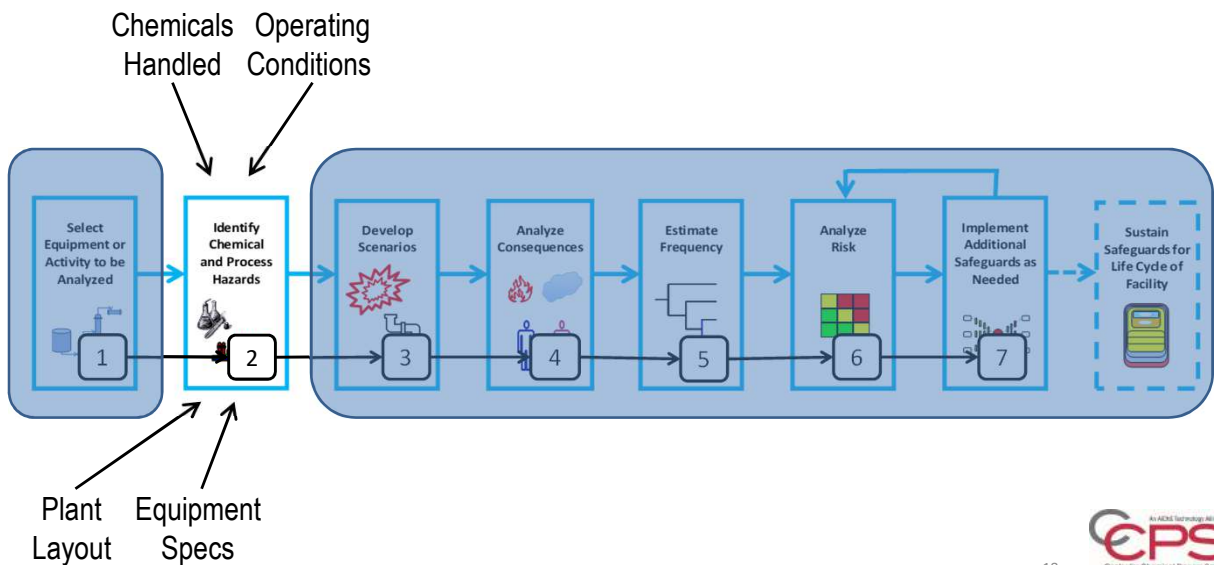
Start by entering Chlorine Rail Car information

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

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date 4/12/22
Go to Revision Log >

Import from Previous Study
Merge Data from Another Study into this Study
Update Previously Saved Information
Access LOPA Workbook from Scenario Results
Update Notes and Comments for Entire Workbook

Go to Equipment Table >
Go To Scenario Results >
Go to Workbook Notes >

Select Default Units: English Units SI Units Study File: rkanalysiscreeningtoolv41 - Copy.xlsx

Session Date: 28-Oct-2022 Participants: Bruce and Jennifer

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Equipment Location: Outdoors
Data Entry Status or Notes:

Plant Section or Sub-Area: DPC Enterprises
P&ID Number:

Input Information
Chemical Data Input ☒
Equipment Data Input ☐
Process Conditions Input ☐
Plant Layout Input ☐
Reaction Input and Evaluation ☐
Input Guidance Information ☐

Check Inputs
Save Inputs to Equipment Table
Update Scenarios for Equipment Loaded
LOPA Menu >

Fire & Explosion Index / Chemical Exposure Index
Hazards & Consequences
Scenario Identification
Relief Effluent Screening
Pool Fire Evaluation

Insufficient Input Data to Proceed with Analysis, Critical Errors = 17

Chemical Data Input

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Case Study – Chlorine Release

Chemical Data Input

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

Note what happens if

- Operating data is
Pressure 115 psig
Temperature 77 °F

Chemical Data Input

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Equipment Location: Outdoors
Data Entry Status or Notes:

Plant Section or Sub-Area: DPC Enterprises
P&ID Number:

Chemical Data Input
Chemical Name: Chlorine
Chemical Formula: Cl2
Chemical Weight: 70.906 g/mol
Chemical Density: 3.201 g/cm3
Chemical Boiling Point: 34.3 °C
Chemical Melting Point: -101.06 °C
Chemical Vapor Pressure: 10.13 kPa
Chemical Flash Point: -112.8 °C
Chemical Autoignition Temperature: 1125 °C
Chemical Decomposition Temperature: 1700 °C
Chemical Heat of Vaporization: 29.8 kJ/mol
Chemical Heat of Fusion: 1.6 kJ/mol
Chemical Heat of Combustion: 0 kJ/mol
Chemical Specific Heat: 0.85 kJ/kg·K
Chemical Thermal Conductivity: 0.016 W/m·K
Chemical Diffusivity: 0.0001 m2/s
Chemical Viscosity: 0.0001 Pa·s
Chemical Surface Tension: 0.022 N/m
Chemical Critical Temperature: 144 °C
Chemical Critical Pressure: 7.6 MPa
Chemical Critical Density: 480 kg/m3
Chemical Critical Volume: 0.00025 m3/mol
Chemical Critical Compressibility: 0.25
Chemical Critical Speed of Sound: 300 m/s
Chemical Critical Heat Capacity: 100 J/mol·K
Chemical Critical Enthalpy: 100 kJ/mol
Chemical Critical Entropy: 100 J/mol·K
Chemical Critical Gibbs Free Energy: 100 kJ/mol
Chemical Critical Helmholtz Free Energy: 100 kJ/mol
Chemical Critical Internal Energy: 100 kJ/mol
Chemical Critical Enthalpy of Formation: 100 kJ/mol
Chemical Critical Entropy of Formation: 100 J/mol·K
Chemical Critical Gibbs Free Energy of Formation: 100 kJ/mol
Chemical Critical Helmholtz Free Energy of Formation: 100 kJ/mol
Chemical Critical Internal Energy of Formation: 100 kJ/mol

Operating Pressure and Temperature

Saturation Temperature and Physical State (Liquid)

RAST allows up to 5 components.

RAST prepopulates data based on chemical library
User defined option, too

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Case Study – Chlorine Release

Main Menu

Chemical Data Input
"Min Complete" - Green

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

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date 4/12/22
Go to Revision Log >

Import from Previous Study
Merge Data from Another Study into this Study
Update Previously Saved Information
Access LOPA Workbook from Scenario Results
Update Notes and Comments for Entire Workbook

Import from RAST File
Merge Data from Another File
Go to Equipment Table >
Go To Scenario Results >
Go to Workbook Notes >

SI Units Study File: RAST Software Workshop Nov TSC.xlsm
Participants: TSC Participants

Location = Chlorine Rail Car
Type = Tank Truck/Rail Car/Tote
Environment Location = Outdoors
Status or Notes:
Plant or Sub-Area: DPC Enterprises
ID Number:

Input Information
Min Complete
Equipment Parameter Input
Process Conditions Input
Plant Layout Input
Reaction Input and Evaluation
Input Guidance Information

Check Inputs
Save Inputs to Equipment Table
Update Scenarios for Equipment Loaded
LOPA Menu >

Scenario Identification
Relief Effluent Screening
Pool Fire Evaluation

Insufficient Input Data to Proceed with Analysis, Critical Errors = 3

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Case Study – Chlorine Release

Equipment Input

Chlorine Rail Car capacity
90 m³ (17,300 gal)
Maximum Allowable Working Pressure (MAWP)
26 barg (375 psig)

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

Equipment Input
Go To Process Conditions Input >
Go To Plant Layout >
Go To Reaction Input >

Go To Equipment Table
Clear Input

Equipment Description

Piping Parameters
Pipe Length = 17300 m
Piping Vulnerable to Damage?
Apply Screwed Connection Penalty?

Pump / Agitator Parameters
Pump Type =
Seal or Containment Type =
Remote Pump Automate
Pump Volume (including piping to block valves) 17.3
Pump Surface (including piping to block valves) 0.06

Transportation Equipment or Piping Parameters
Equipment or Piping Connection = Hose

Other Equipment Parameters

Parameters
Equipment Volume = 17300 gal
MAWP (gauge) = 375 psi
Full Vacuum Rated?
Estimated High Temperature Failure = C
Estimated Embrittlement Temperature = C
Nozzle or Pipe Size = 1 in
Number of Flanges or Nozzles
Material of Construction
Estimated Equipment Weight = 43965 kg
Insulation
Insulation Heat Reduction Factor =
Tracing?
Estimated Equipment Max Wetted Area = 76 sq m

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Case Study – Chlorine Release

Main Menu

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date 4/12/22
Go to Revision Log >

Import from Previous Study Import from RAST File
Merge Data from Another Study into this Study Merge Data from Another File
Update Previously Saved Information Go to Equipment Table >
Access LOPA Workbook from Scenario Results Go To Scenario Results >
Update Notes and Comments for Entire Workbook Go to Workbook Notes >

SI Units Study File: RAST Software Workshop Nov TSC xlm
Participants: TSC Participants

Location: Chlorine Rail Car
Type: Tank Truck/Rail Car/Tote
Equipment Location: Outdoors
Status or Notes:
Plant or Sub-Area: DPC Enterprises
EID Number:

Input Information
Min Complete
Chemical Data Input
Equipment Parameter Input
Process Conditions Input
Plant Layout Input
Reaction Input and Evaluation
Input Guidance Information

Check Inputs
Go to Equipment Table
Update Scenarios for Equipment Loaded
Scenario Identification
Relief Effluent Screening
Pool Fire Evaluation
LOPA Menu >

Insufficient Input Data to Proceed with Analysis, Critical Errors = 3

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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 °C

<< Go To Main Menu **Process Conditions Input** Go To Plant Layout >
< Go To Chemical Data Save Input to Equipment Table Clear Input Go To Reaction Input >
< Go To Equipment Input

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Location: Outdoors

Process/Operating Conditions

Ambient Temperature =	25	C
Inventory Limit (blank is unlimited) =		kg
Maximum Inventory =		m
Limiting Maximum Fill Fraction =	0.9	
Limiting Minimum Fill Fraction =		
Maximum Feed Press (gauge) =		bar
Maximum Feed or Flow Rate =	0	kg/min
Maximum Storage =		

Search or Continuous
Ventilatable Atmosphere Maintained?
Potential for Aerosol or Mist
Pad Gas Vent Rate =
Max Pad Gas Vent Rate =
Pressure (gauge) =
Maximum Back Flow Rate =
Equipment Vents to =

Process Description
The rail cars are only unloaded such that the maximum fill rate is zero.

Summary for Chlorine

Operating Temperature =	25	C
Operating Pressure (gauge) =	8	bar
Physical State =	Liquid	
Saturation Temperature =	30.4	C
Unleaked Mass =	81592	kg
Inventory Contained Mass =	90658	kg
Inventory for Reference =	90658	kg

Operating Procedures

Percent of Time in Operation =	
Frequent Turnaround or Cleanout?	
Centralized Ventilation Shut-Off Bldg 1?	
Centralized Ventilation Shut-Off Bldg 2?	

Review of Operating Procedures for Selected Equipment Item by: Review Date:

Release for Equipment Rupture? sec

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Main Menu

Tutorial
Check

Three Completed
Input Worksheets
(Boxes are Green)

RAST
Risk Analysis Screening Tools (V 4.1)
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Update Notes and Comments for Entire Workbook: Go to Workbook Notes >

Select Default Units: English Units SI Units Study File: RAST Software Workshop Nov TSC.xlsm

Session Date: 28-Oct-2022 Participants: TSC Participants

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Equipment Location: Outdoors
Data Entry Status or Notes:
Plant Section or Sub-Area: DPC Enterprises
P&ID Number:

Input Information Min Complete
Chemical Data Input ☒
Equipment Parameter Input ☒
Process Conditions Input ☒
Plant Layout Input ☐
Reaction Input and Evaluation
Input Guidance Information

Evaluations and Reports
Check Inputs
Save Inputs to Equipment Table
Update Scenarios for Equipment Loaded
LOPA Menu >
Fire & Explosion Index / Chemical Exposure Index
Hazards & Consequences
Scenario Identification
Relief Effluent Screening
Pool Fire Evaluation

Insufficient Input Data to Proceed with Analysis, Critical Errors = 3

Still Insufficient
Data (Red)

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Case Study – Chlorine Release

Main Menu

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date 4/12/22
Go to Revision Log >

Import from Previous Study: Import from RAST File
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Update Previously Saved Information: Go to Equipment Table >
Access LOPA Workbook from Scenario Results: Go To Scenario Results >
Update Notes and Comments for Entire Workbook: Go to Workbook Notes >

Select Default Units: English Units SI Units Study File: RAST Software Workshop Nov TSC.xlsm

Session Date: 2022-10-28 Participants: TSC Participants

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Equipment Location: Outdoors
Data Entry Status or Notes:
Plant Section or Sub-Area: DPC Enterprises
P&ID Number:

Input Information Min Complete
Chemical Data Input ☒
Equipment Parameter Input ☒
Process Conditions Input ☒
Plant Layout Input ☒
Reaction Input and Evaluation
Input Guidance Information

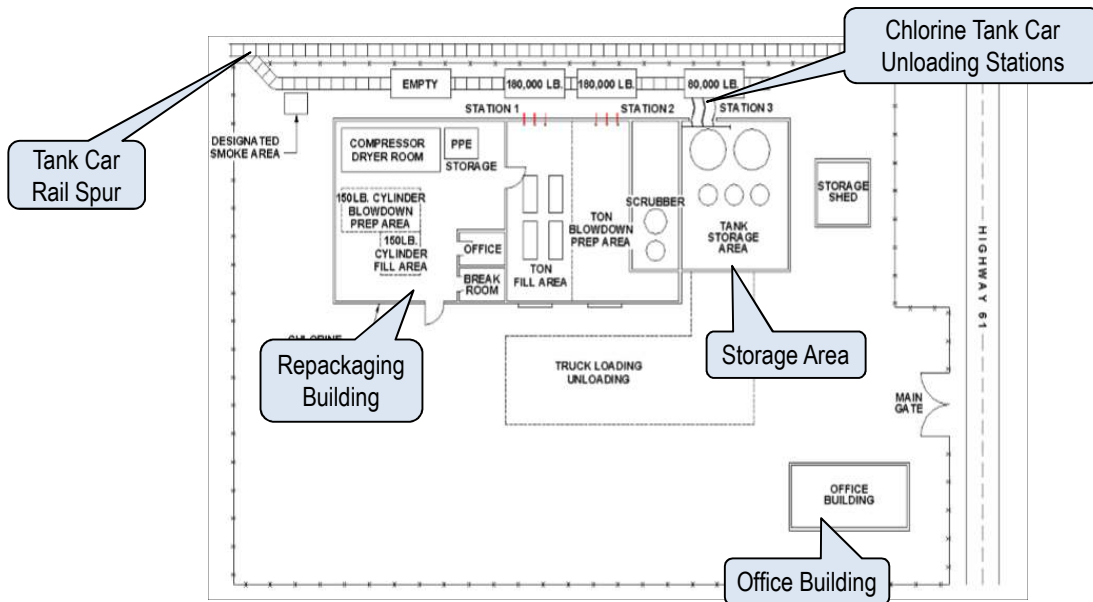
Evaluations and Reports
Check Inputs
Save Inputs to Equipment Table
Update Scenarios for Equipment Loaded
LOPA Menu >
Fire & Explosion Index / Chemical Exposure Index
Hazards & Consequences
Scenario Identification
Relief Effluent Screening
Pool Fire Evaluation

Input Data Sufficient to Proceed with Analysis

Step 2 Continued
Go to Plant Layout Input

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Case Study – Chlorine Release

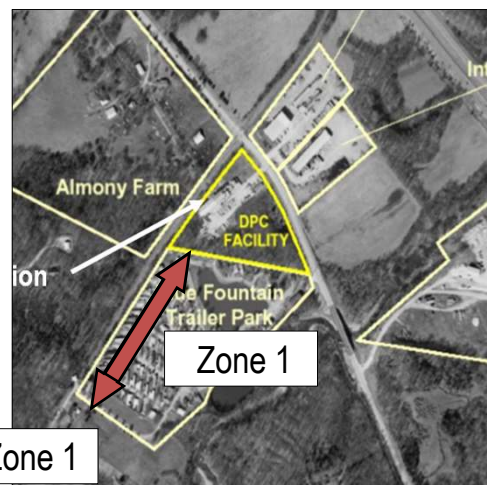


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Case Study – Chlorine Release

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/m²
Rural homes/farms
"Beyond Zone 1"



2E-4 people/m²
Residential homes on
very large plots



1.5E-3 people/m²
Typical suburban
residential area



3E-3 people/m²
Mobile Homes (upper
end of Moderate)
"Zone 1"

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Case Study – Chlorine Release

Examples of Densely populated areas



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

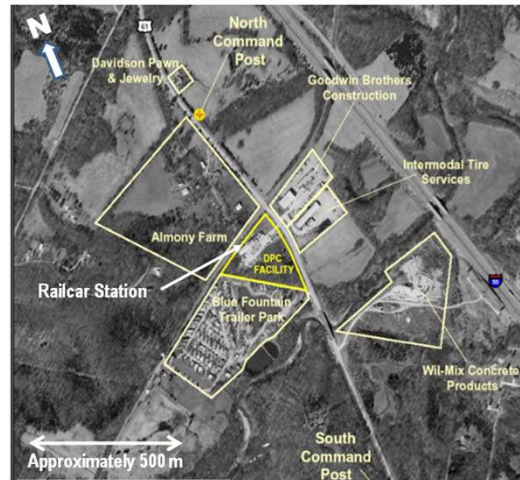
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Case Study – Chlorine Release

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

Zone 1

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/m²

Beyond Zone 1

Beyond the mobile home park

- Rural
- Population density 0.0001 people/m²

Location Information

Plant Layout		Location Information	
Equipment Identification: Chlorine Rail Car Equipment Type: Tank Truck/Rail Car Location: Outdoor		Layout Description:	
Location Information Distance to Property Limit or Fence Line = 100 m Furthest Distance to Fence Line (> 100 m) = Max. Onsite Outdoor Population Density = 0.003 people/m ² Personnel Routinely in Immediate Area? Yes Distance to end of Offsite Zone 1 = 500 m Offsite Population Density within Zone 1 = 0.003 people/m ² Offsite Population Density Beyond Zone 1 = 0.0001 people/m ² Effective Egress from Work Area? Access for Emergency Services? Degree of Equipment Congestion in Area? Containment or Dike Surface Area = Consider Dike or Bund Failure for Vessel Rupture? Credit Fire Heat Adsorption for Drainage/Inflow? Distance to Nearest Fire Equipment = Quantity of "Other" Flammables in Immediate Area = Quantity of Flammables in Adjacent Area = Adjacent Containment or Dike Surface Area = Automated EGVs to limit spill quantity?		Occupied Building Data Occupied Building 1 Name = Site Office Distance to Occupied Bldg 1 or Area = 50 m Elevation of Occ Bldg 1 Ventilation Inlet = Distance to Center of Occupied Bldg 1 = Occupied Bldg Type = Occupied Bldg Ventilation Rate = changes/hr Number of Building Occupants = 5 Occ Bldg 2 in Same Wind Direction? No Occupied Building 2 Name = Goodwin Brothers/Interm Distance to Occupied Bldg 2 = 200 m Elevation of Occ Bldg 2 Ventilation Inlet = Distance to Center of Occ. Bldg 2 = Occupied Bldg 2 Type = Occupied Bldg 2 Ventilation Rate = changes/hr Number of Occupants Bldg 2 = 30	
Enclosed Process Area Data Enclosed Process Volume = cu m Enclosed Process Ventilation = changes/hr No. Enclosed Area Personnel =		Environmental Inputs Spills to Soil Require Remediation? Potential for Water Contamination? High Population Downstream of Facility? Note that Environmental Scenarios are Excluded	

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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

Plant Layout Input

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Location: Outdoors

Location Information

Distance to Property Limit or Fence Line =	100	m
Furthest Distance to Fence Line (> 100 m) =		m
Max. Onsite Outdoor Population Density		people/m ²
Personnel Routinely in Immediate Area?	Yes	
Distance to end of Offsite Zone 1	500	m
Offsite Population Density within Zone 1	0.003	people/m ²
Offsite Population Density Beyond Zone 1	0.0001	people/m ²
Effective Egress from Work Area?		
Access for Emergency Services?		
Degree of Equipment Congestion in Area?		
Containment or Dike Surface Area =		sq m
Consider Dike or Bund Failure for Vessel Rupture?		
Credit Fire Heat Adsorption for Drainage/Indirect?		
Distance to Nearest Fire Equipment =		m
Quantity of Other Flammables in Immediate Area		kg
Quantity of Flammables in Adjacent Area		kg
Adjacent Containment or Dike Surface Area =		sq m
Automated EBU to limit spill quantity?		

Enclosed Process Area Data

Enclosed Process Volume =		cu m
Enclosed Process Ventilation =		changes/hr
No. Enclosed Area Personnel =		

Occupied Building Data

Occupied Building 1 Name = Site Office

Distance to Occupied Bldg 1 or Area =	50	m
Elevation of Occ Bldg 1 Ventilation Inlet =		m
Distance to Center of Occupied Bldg 1 =		m
Occupied Bldg Type =		
Occupied Bldg Ventilation Rate =		changes/hr
Number of Building Occupants =	5	
Occ Bldg 2 in Same Wind Direction?	No	
Occupied Building 2 Name =	Goodwin Bothers/Intermodal	
Distance to Occupied Bldg 2	200	m
Elevation of Occ Bldg 2 Ventilation Inlet =		m
Distance to Center of Occ. Bldg2 =		m
Occupied Bldg 2 Type =		
Occupied Bldg 2 Ventilation Rate =		changes/hr
Number of Occupants Bldg 2 =	30	

Environmental Inputs

Spills to Soil Require Remediation?	
Potential for Water Contamination?	
High Population Downstream of Facility?	

Note that Environmental Scenarios are Excluded

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Case Study – Chlorine Release

Plant Layout Input

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Location: Outdoors

Location Information

Distance to Property Limit or Fence Line =	100	m
Furthest Distance to Fence Line (> 100 m) =		m
Max. Onsite Outdoor Population Density		people/m ²
Personnel Routinely in Immediate Area?	Yes	
Distance to end of Offsite Zone 1	500	m
Offsite Population Density within Zone 1	0.003	people/m ²
Offsite Population Density Beyond Zone 1	0.0001	people/m ²
Effective Egress from Work Area?		
Access for Emergency Services?		
Degree of Equipment Congestion in Area?		
Containment or Dike Surface Area =		sq m
Consider Dike or Bund Failure for Vessel Rupture?		
Credit Fire Heat Adsorption for Drainage/Indirect?		
Distance to Nearest Fire Equipment =		m
Quantity of Other Flammables in Immediate Area		kg
Quantity of Flammables in Adjacent Area		kg
Adjacent Containment or Dike Surface Area =		sq m
Automated EBU to limit spill quantity?		

Enclosed Process Area Data

Enclosed Process Volume =		cu m
Enclosed Process Ventilation =		changes/hr
No. Enclosed Area Personnel =		

Occupied Building Data

Occupied Building 1 Name = Site Office

Distance to Occupied Bldg 1 or Area =	50	m
Elevation of Occ Bldg 1 Ventilation Inlet =		m
Distance to Center of Occupied Bldg 1 =		m
Occupied Bldg Type =		
Occupied Bldg Ventilation Rate =		changes/hr
Number of Building Occupants =	5	
Occ Bldg 2 in Same Wind Direction?	No	
Occupied Building 2 Name =	Goodwin Bothers/Intermodal	
Distance to Occupied Bldg 2	200	m
Elevation of Occ Bldg 2 Ventilation Inlet =		m
Distance to Center of Occ. Bldg2 =		m
Occupied Bldg 2 Type =		
Occupied Bldg 2 Ventilation Rate =		changes/hr
Number of Occupants Bldg 2 =	30	

Environmental Inputs

Spills to Soil Require Remediation?	
Potential for Water Contamination?	
High Population Downstream of Facility?	

Note that Environmental Scenarios are Excluded

Save Inputs to Equipment Table
(Blue Macro Button)

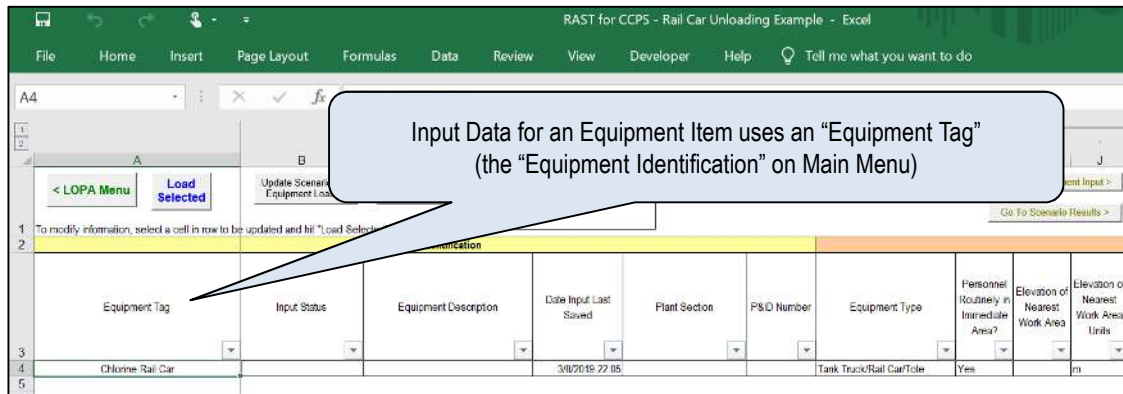
Sends you to the
Equipment Table

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Case Study – Chlorine Release

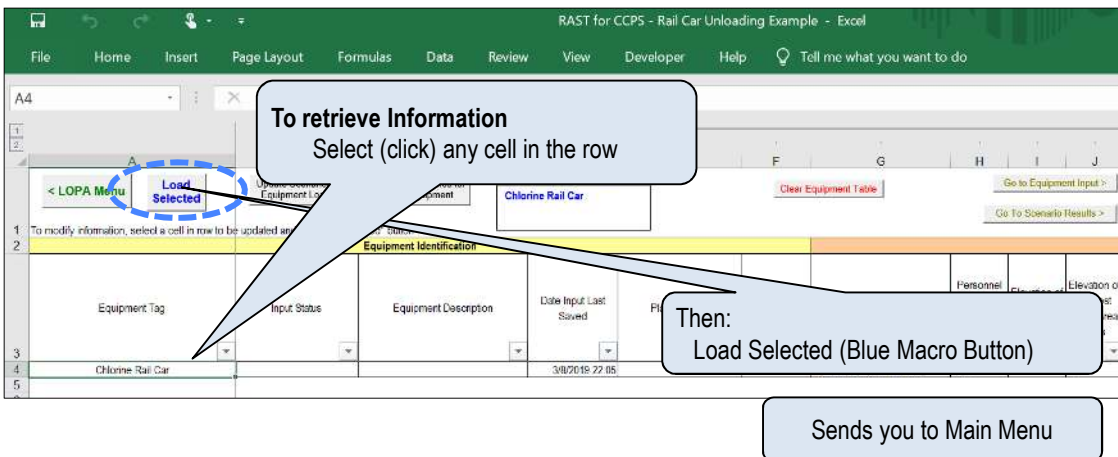
Input stored in the Equipment Table

Single row contain the equipment information (only one entered for Tutorial)



35

Case Study – Chlorine Release



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Case Study – Chlorine Release

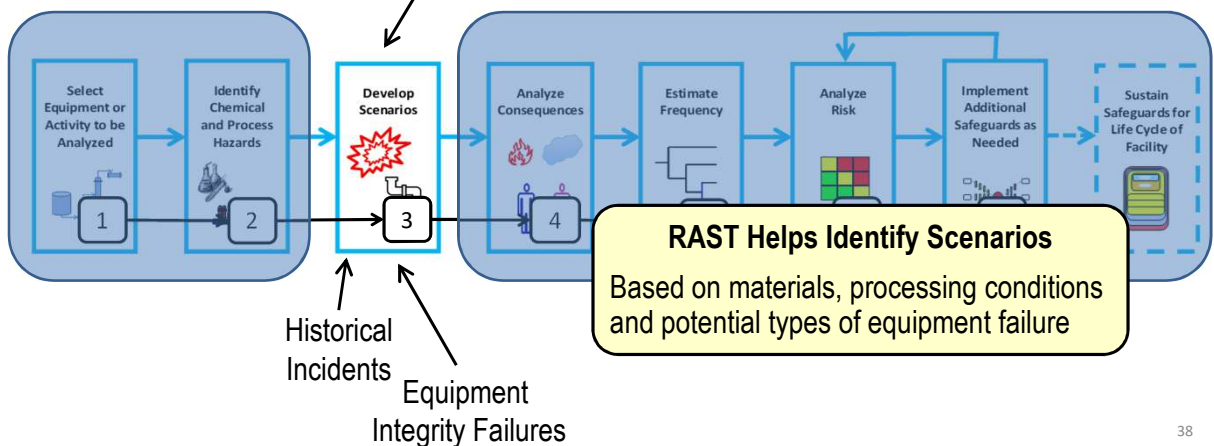
Main Menu

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)



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Case Study – Chlorine Release

Main Menu

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date 4/12/22
Go to Revision Log >

Import from Previous Study Import from RAST File
Merge Data from Another Study into this Study Merge Data from Another File
Update Previously Saved Information Go to Equipment Table >
Access LOPA Workbook from Scenario Results Go To Scenario Results >
Update Notes and Comments for Entire Workbook Go to Workbook Notes >

Select Default Units: **English Units** SI Units Study File: RAST Software Workshop Nov TSC xlsx

Session Date: 2022-10-28 Participants: TSC Participants

Equipment Identification:
Equipment Type: Chlorine Rail Car
Equipment Location: Tank Truck/Rail Car/Tote
Data Entry Status or Notes: Outdoors
Plant Section or Sub-Area: DPC Enterprises
PID Number:

Input Information **Evaluations and Reports**

Chemical Data Input ☐ Check Inputs
Equipment Parameter Input ☐ Save Inputs to Equipment Table
Process Conditions Input ☐ Update Scenarios for Equipment Loaded
Plant Layout Input ☐ LOPA Menu >
Reaction Input and Evaluation ☐ Pool Fire Evaluation
Input Guidance Information ☐ Relief Effluent Screening

Fire & Explosion Index / Chemical Exposure Index
Scenario Identification
Relief Effluent Screening
Pool Fire Evaluation

Input Data Sufficient to Proceed with Analysis

Step 3
Go to Scenario Identification

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Case Study – Chlorine Release

Suggested Scenarios for Rail Car

<< Go To Main Menu Suggested Scenarios from the RAST Library

Update List Create User Scenario LOPA Menu Filters: Scenario Type Scenario C

Plant Section = DPC Enterprises
Equipment Type = Tank Truck/Rail Car/Tote
Equipment Tag = Chlorine Rail Car

Chlorine Rail Car is a Tank Truck/Rail Car/Tote containing Chlorine that operates at 25 C and 8 bar. The volume is 17,300 gal with a maximum allowable working pressure of 375 psi. The maximum feed or flow rate is 0 l/min.

Scenarios in gray were suggested to be excluded for reason noted under Scenario Comments. Study Team should review each to determine if excluding from Risk Analysis is appropriate.

Required will NOT be reported. Missing Inputs for Session Date or Participants

Initiating Event Description	Loss Event	Outcome	Severity	Frequency	Existing Safeguards	Recommendations	Further Analysis
Overhead incident in main tank or car	Full Bow Hole Size Leak	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5	Chassis placed on wheels during loading or unloading	Potential Consequence Severity High such that further analysis is warranted.	Yes
Drain or Vent Valve left open following loading/unloading or batch transfer	Drain or Vent Leak	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5	Blind flange or plug required on all blind valves	Potential Consequence Severity High such that further analysis is warranted.	Yes
Hose or Loading Arm Connection	Spill associated with improper connection of hose or loading arm	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5	All connections leak checked before loading or unloading	Potential Consequence Severity High such that further analysis is warranted.	Yes
Piping or Equipment Leaking	Full Bow Hole Size Leak	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5		Potential Consequence Severity High such that further analysis is warranted.	Yes
Excessive Heat Input - Heat Transfer	Not Set	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5		Potential Consequence Severity High such that further analysis is warranted.	Yes
Excessive Relief Valve Pressure	Regulator Failure	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5		Potential Consequence Severity High such that further analysis is warranted.	Yes
Excessive Relief Valve Pressure	Regulator Failure	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5		Potential Consequence Severity High such that further analysis is warranted.	Yes
Excessive Relief Valve Pressure	Regulator Failure	On-Die Toxic Release, On-Die Toxic Release, Toxic Inhibition	5	5		Potential Consequence Severity High such that further analysis is warranted.	Yes

RAST contains a Library of potential incident scenarios

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

PHA Team Reviews for Feasibility

Update Input this worksheet
Clear Input this Worksheet
Save Input to Equipment Table

Go To Scenario Results >

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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

Additional Scenarios can be added by using "Create User Scenario"

Suggested Scenarios from the RAST Library

Session Date:
 Session Participants:
 Save Input to Equipment Library

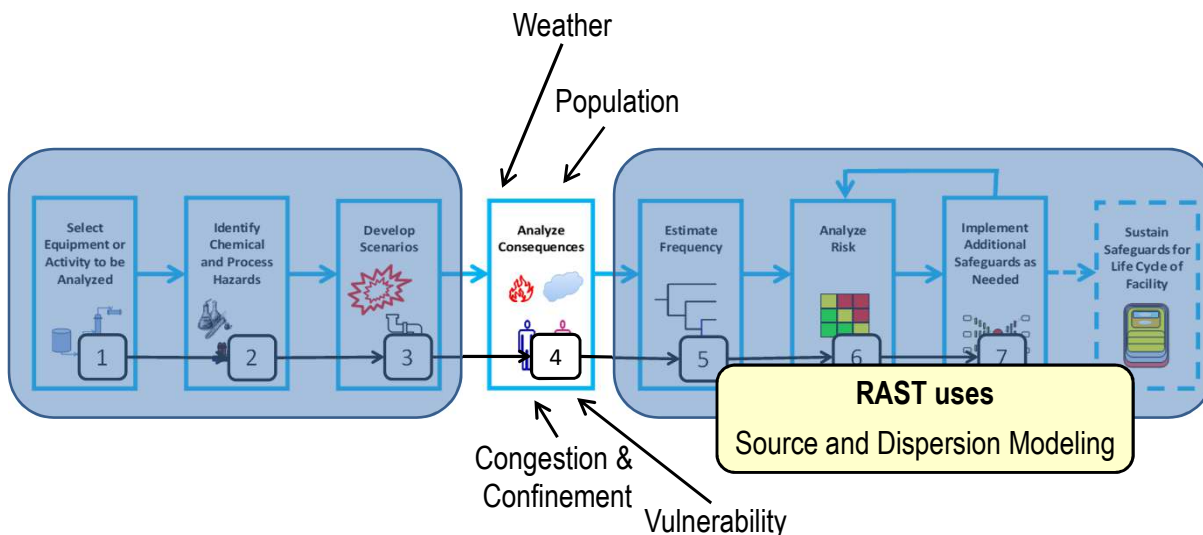
Scenario Type	Scenario Comments	Parameters and Deviation	Initiating Event (Cause)	Initiating Event Description	Loss Event	Outcome	Existing Safeguards	Recommendations	Further Analysis
Damage from Movement	Spill caused by Truck or car movement while transfer in progress	Flow Loss of Containment	3rd Party Intervention	Driver inadvertently moves truck or car	Full Discharge	On-Off Toxic Release, On-Off Toxic Release, Toxic Ingestion	Checks placed on wheels during loading or unloading	Potential Consequence Severity High such that further analysis is warranted.	Yes
Open or Vent Valve Open	Open or Vent Valve left open following loading/unloading or batch transfer	Flow Loss of Containment	Human Failure Action more than once per quarter	Operator leaves Open or Vent Open following unloading or unloading	Open or Vent Leak	On-Off Toxic Release, On-Off Toxic Release, Toxic Ingestion	Blind flange or plug required on all vented valves	Potential Consequence Severity High such that further analysis is warranted.	Yes
Hose or Loading Arm Connection	Spill associated with improper connection of hose or loading arm	Flow Loss of Containment	Human Failure Action more than once per quarter	Operator fails to ensure proper connection before starting material transfer	Gasket Failure	On-Off Toxic Release, On-Off Toxic Release, Toxic Ingestion	All connections leak checked before loading or unloading	Potential Consequence Severity High such that further analysis is warranted.	Yes
Piping or Equipment Leak - Full Size	Assessment Excludes Mechanical Integrity Scenarios	Flow Loss of Containment	Unloading/Loading Hose Failure	Failure of hose from fatigue, etc.	Full Size Hole Size Leak	On-Off Toxic Release, On-Off Toxic Release, Toxic Ingestion		Potential Consequence Severity High such that further analysis is warranted.	Yes
Excessive Heat Input - Heat Transfer	No Heating Media Temperature was noted	Pressure High	SPCS Instrument Loop Failure	Failure of Flow Control	On-Off Triggering Incident Not Met				
Excessive Pail Gas Pressure	Maximum Pail Gas Pressure Does Not Detect the Maximum Allowable Working Pressure or Relief Set Pressure	Flow High	Regulator Failure	Regulator/Fails causing high flow or pressure	On-Off Triggering Incident Not Met				
			SPCS Instrument Loop Failure	Failure of Level Indication with pressure and temperature					

Select "Yes" for Further Analysis

PHA Team Adds or Removes Potential Scenarios

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Step 4 – Analyze Consequences



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Case Study – Chlorine Release

Main Menu

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date 4/12/22
Go to Revision Log >

Import from Previous Study | Import from RAST File
Merge Data from Another Study into this Study | Merge Data from Another File
Update Previously Saved Information | Go to Equipment Table >
Access LOPA Workbook from Scenario Results | Go To Scenario Results >
Update Notes and Comments for Entire Workbook | Go to Workbook Notes >

Select Default Units: **English Units** | SI Units | Study File: RAST Software Workshop Nov TSC xlm

Session Date: 2022-10-28 | Participants: TSC Participants

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank Truck/Rail Car/Tote
Equipment Location: Outdoors
Data Entry Status or Notes:
Plant Section or Sub-Area: DPC Enterprises
P&ID Number:

Input Information | **Evaluations and Reports**

Chemical Data Input | Check Inputs
Equipment Parameter Input | Save Inputs to Equipment Table
Process Conditions Input | Update Scenarios for Equipment Loaded
Plant Layout Input
Reaction Input and Evaluation
Input Guidance Information | LOPA Menu >

Fire & Explosion Index / Chemical Engineering Index
Hazards & Consequences
Score: 1000
Relief Effluent Screening
Pool Fire Evaluation

Input Data Sufficient to Proceed with Analysis

Step 4
Go to Hazards and Consequences

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Case Study – Chlorine Release Consequence Analysis

Scroll right to **CONSEQUENCE SUMMARY**

HAZARD SUMMARY
RAST Version 4.1 | Date: 2022-10-28
for Process Unit: Tank Truck/Rail Car/Tote;
Chlorine Rail Car

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**

Airborne Quantity Summary: Release Temperature: 25.0 | Location: Outdoors | Prob of Exposure (proximity based with Personnel in Immediate Area): Factor: Probability

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 noted)	
Max Distance to Time-Scaled ERPG-2, m	10375.0
Max Distance to Time-Scaled ERPG-3, m	3642.1
Max Distance to LC-50 for 15°F weather, m	1889.6
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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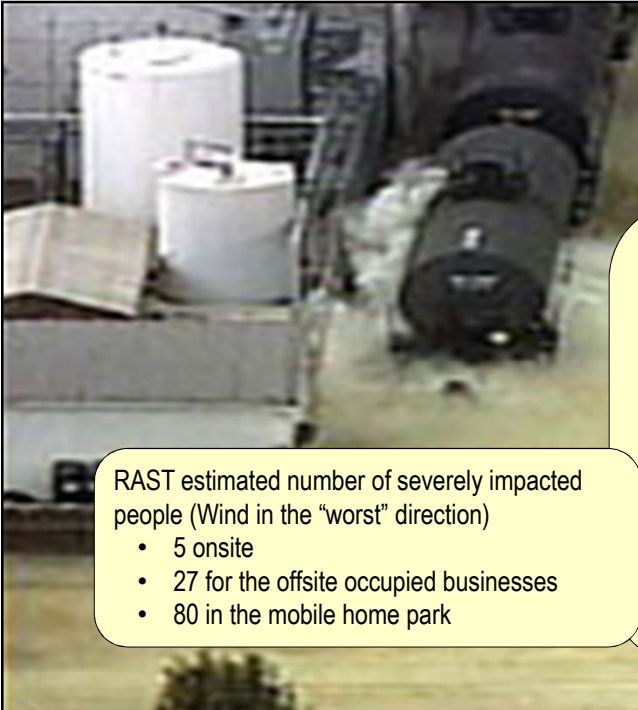
Case Study – Chlorine Release Consequence Analysis

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:	
Impact Assessment with Personnel routinely in the immediate area	Exceeds Threshold
Offsite Toxic Impact based on Toxic Integration Method and 100 m to Fence Line with potential for 80.2 people	Yes
Onsite Toxic Impact based on Distance to LC-50 Concentration	Yes
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 to	
Onsite Thermal Radiation Impact based on Distance from Fireball	
Number of Potential Severe Toxic Impacts Onsite: 16.8 people	
Number of Potential Severe Flash Fire Impacts Onsite: 0 people	
Occupied Building Toxic Impact	Yes
Number of Potential Severe Impacts for Building 1: 5 people	5
Number of Potential Severe Impacts for Building 2: 26.7 people	
Occupied Building Impact from Vapor Cloud Explosion	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	
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

At time incident (*changed RAST Defaults*)

- 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)

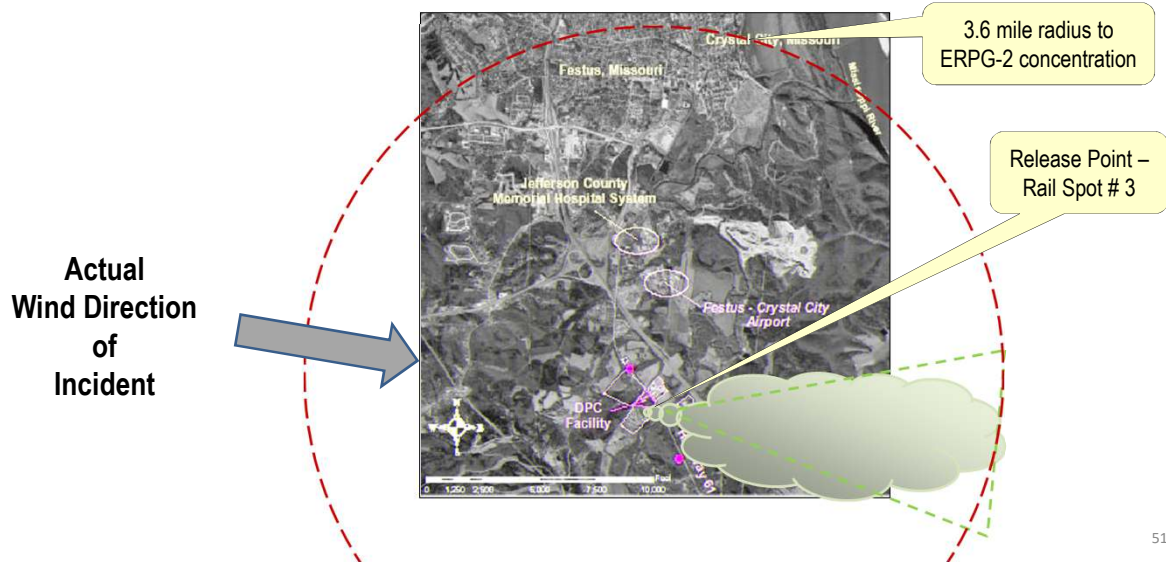
Considering assumptions, "good" agreement with CSB

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

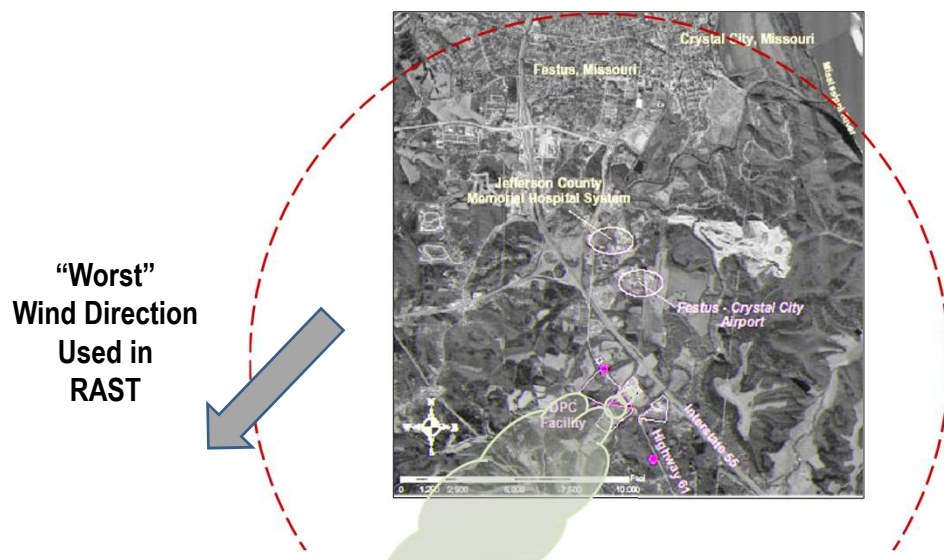


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Case Study – Chlorine Release Consequence Analysis



Case Study – Chlorine Release Consequence Analysis



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.

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Case Study – Chlorine Release

Main Menu

RAST
Risk Analysis Screening Tools (V 4.1)
Latest Revision Date: 4/12/22
[Go to Revision Log >](#)

[CLEAR EVERYTHING IN WORKBOOK](#) [Clear Input](#)

Import from Previous Study: [Import from RAST File](#)

Merge Data from Another Study into this Study: [Merge Data from Another File](#)

Update Previously Saved Information: [Go to Equipment Table >](#)

Access LOPA Workbook from Scenario Results: [Go To Scenario Results >](#)

Update Notes and Comments for Entire Workbook: [Go to Workbook Notes >](#)

Select Default Units: [English Units](#) [SI Units](#) Study File: [RAST Software Workshop Nov TSC.xlsm](#)

Session Date: [2022-10-28](#) Participants: [TSC Participants](#)

Equipment Identification: [Chlorine Rail Car](#)

Equipment Type: [Tank Truck/Rail Car/Tote](#)

Equipment Location: [Outdoors](#)

Data Entry Status or Notes: [DPC Enterprises](#)

Plant Section or Sub-Area: [P&ID Number](#)

Input Information [Min Complete](#)

[Chemical Data Input](#) [Check Inputs](#)

[Equipment Parameter Input](#) [Save Inputs to Equipment Table](#)

[Process Conditions Input](#) [Update Scenarios for Equipment Loaded](#)

[Plant Layout Input](#) [LOPA Menu >](#)

[Reaction Input and Evaluation](#) [Input Guidance Information](#)

Evaluations and Reports

[Fire & Explosion Index / Chemical Exposure Index](#)

[Scenario Identification](#)

[Relief Effluent Screening](#)

[Pool Fire Evaluation](#)

[Input Data Sufficient to Proceed with Analysis](#)

Go to Scenario Identification

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Case Study – Chlorine Release

Suggested Scenarios for Rail Car

Potential Outcome and Tolerable Frequency Factors
0 is low risk
6 is higher risk, needs more protection layers

Piping or Equipment Leak, Full Bore

Piping or Equipment Leak, Full Bore

Potential Outcome / Tolerable Frequency

Go To Scenario Results >

Update Input this worksheet

Clear Input this Worksheet

Save Input to Equipment Table

Scenario Outcome

Off-site Toxic Release - 6
On-site Toxic release - 6
Toxic Infiltration - 6

Scenario Type

Scenario Description

Loss Event

Outcome

Existing Safeguards

Recommendations

Further Analysis

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Case Study – Chlorine Release

Suggested Scenarios for Rail Car

Scenario Outcome
Off-site Toxic Release - 6
On-site Toxic release - 6
Toxic Infiltration - 6

Scenario Type

Scenario Description

Loss Event

Outcome

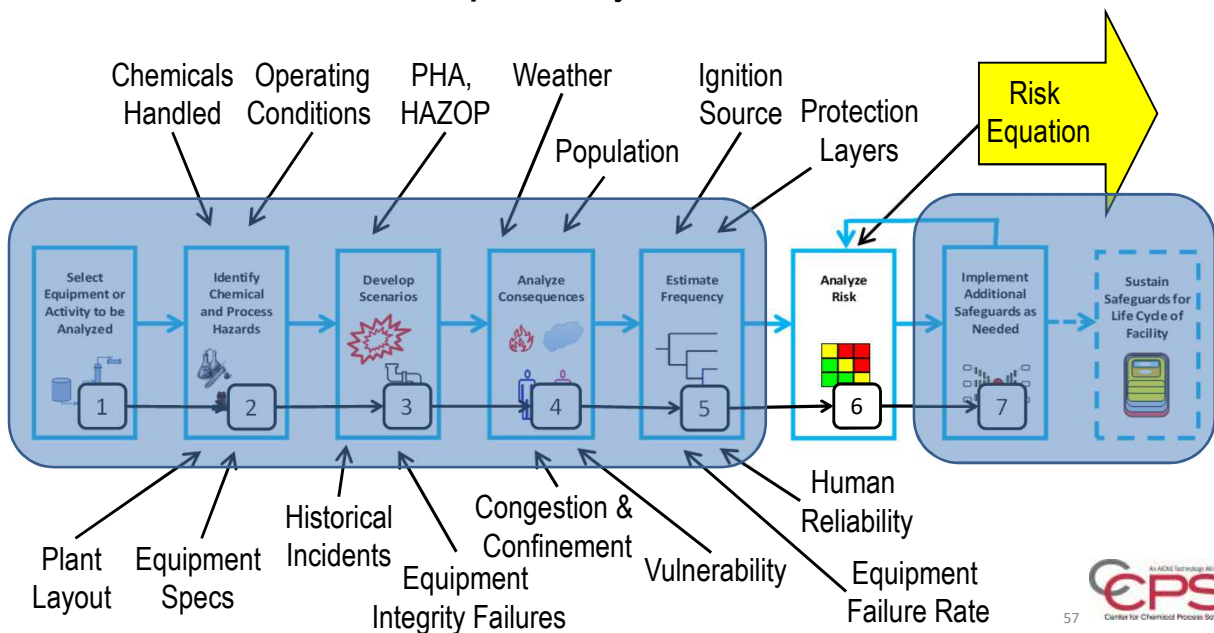
Existing Safeguards

Recommendations

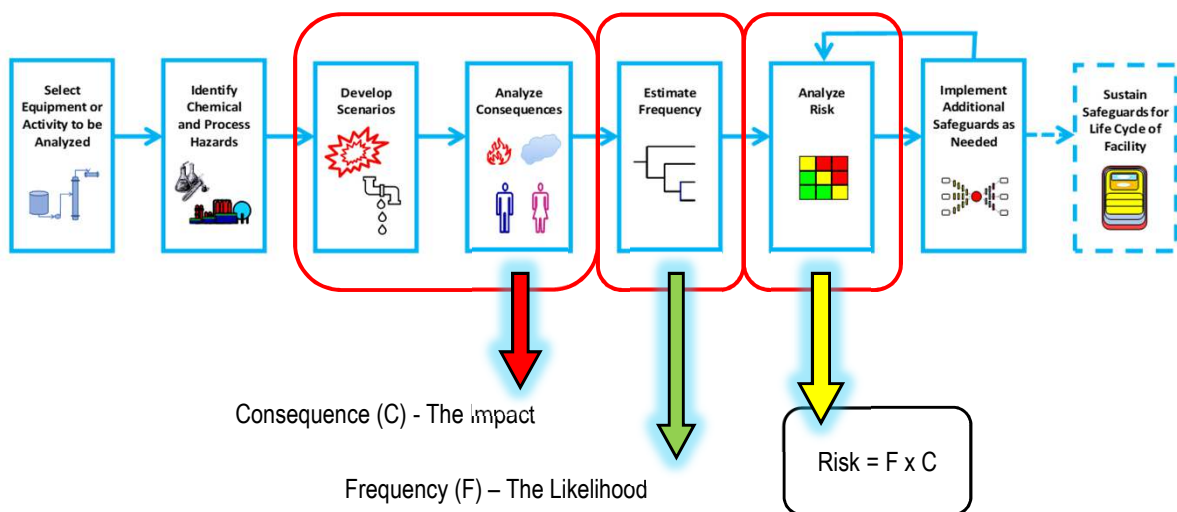
Further Analysis

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Step 6 – Analyze Risk



Risk Screening Estimates using RAST



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?”

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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



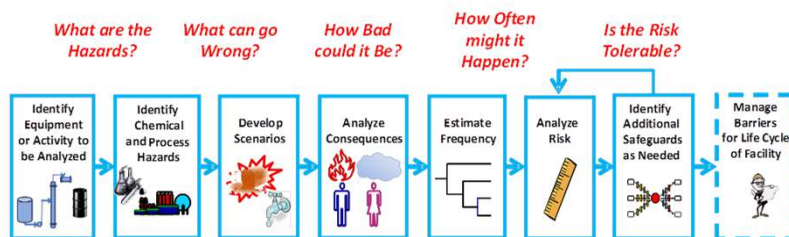
(COURTESY KTVI)

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

March 24, 2022

Slide - 1

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.

March 24, 2022

Slide - 2

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.

March 24, 2022

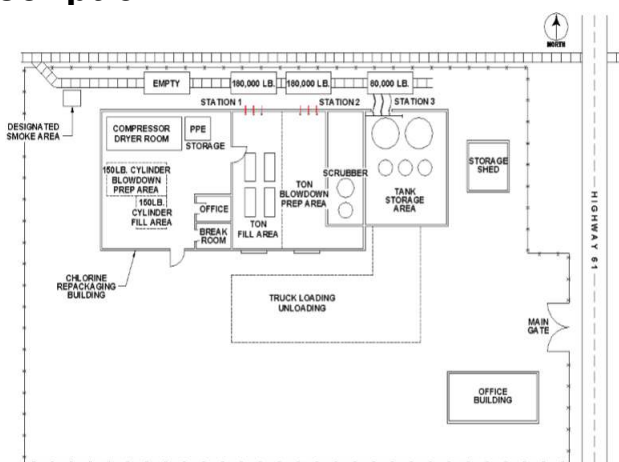
Slide - 3

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.



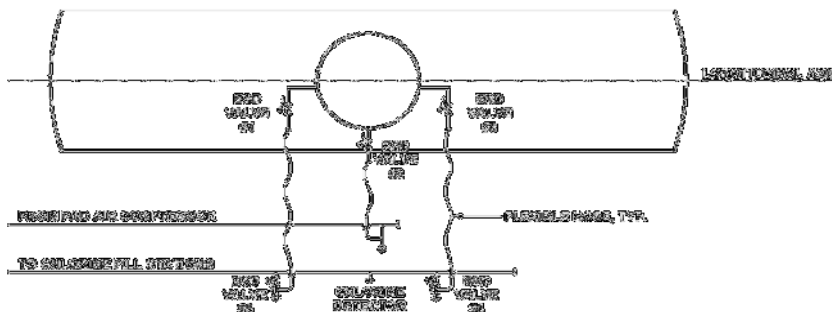
March 24, 2022

Slide - 4

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 Down 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.



March 24, 2022

Slide - 5

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.

On 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.

March 24, 2022

Slide - 6

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

March 24, 2022

Slide - 7

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

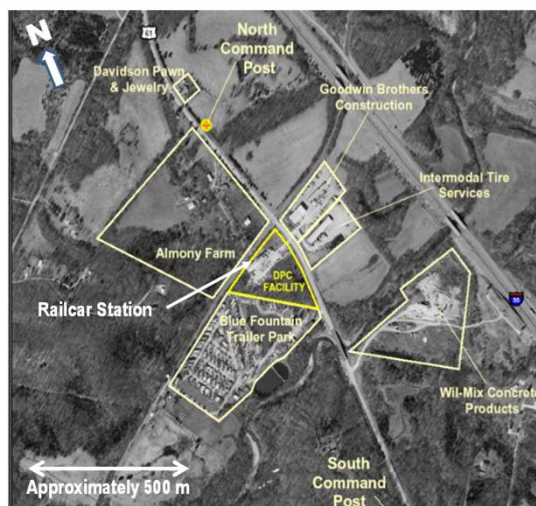
March 24, 2022

Slide - 8

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



March 24, 2022

Slide - 11

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/m²
Rural homes/farms



2E-4 people/m²
Residential homes on very large plots

March 24, 2022

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Case Study – Chlorine Repackaging Site Layout

Examples of Moderately 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

March 24, 2022

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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.

Plant Layout Input

Go To Main Menu | Save Input to Equipment Table | Clear Input | Go To Reaction Input | Go To Process Conditions

Equipment Identification: Chlorine Rail Car
Equipment Type: Tank/Track/Rail Car/Tote
Location: Outdoors

Location Information

Distance to Property Limit or Fence Line =	100	m
Furthest Distance to Fence Line (> 100 m) =		
Max. Onsite Outdoor Population Density Personnel Routinely in Immediate Area?	Yes	
Distance to end of Offsite Zone 1	500	m
Offsite Population Density within Zone 1	0.003	people/m ²
Offsite Population Density Beyond Zone 1	0.0001	people/m ²
Effective Egress from Work Area?		
Access for Emergency Services?		
Degree of Equipment Congestion in Area?		
Containment or Dike Surface Area =		sq m
Consider Dike or Bund Failure for Vessel Rupture?		
Credit Fire Heat Adsorption for Drainage/Indirect?		
Distance to Nearest Fire Equipment =		
Quantity of "Other" Flammables in Immediate Area		kg
Quantity of Flammables in Adjacent Area		kg
Adjacent Containment or Dike Surface Area =		sq m
Automated ERTs to limit spill quantity?		

Enclosed Process Area Data

Enclosed Process Volume =		cu m
Enclosed Process Ventilation =		changes/hr
No. Enclosed Area Personnel =		

Layout Description

Occupied Building Data

Occupied Building 1 Name =	Site Office	
Distance to Occupied Bldg 1 or Area =	50	m
Elevation of Occ Bldg 1 Ventilation Inlet =		m
Distance to Center of Occupied Bldg 1 =		m
Occupied Bldg Type =		
Occupied Bldg Ventilation Rate =		changes/hr
Number of Building Occupants =	5	
Occ Bldg 2 in Same Wind Direction?	No	
Occupied Building 2 Name =	Goodwin Brothers/Interm	
Distance to Occupied Bldg 2	200	m
Elevation of Occ Bldg 2 Ventilation Inlet =		m
Distance to Center of Occ. Bldg2 =		m
Occupied Bldg 2 Type =		
Occupied Bldg 2 Ventilation Rate =		changes/hr
Number of Occupants Bldg 2 =	30	

Environmental Inputs

Spills to Soil Require Remediation?		
Potential for Water Contamination?		
High Population Downstream of Facility?		

Note that Environmental Scenarios are Excluded

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Risk Analysis Screening Tools (RAST) Case Study – Chlorine Repackaging

Select **Save Inputs to Equipment Table** (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.

Retrieve Information for an Equipment Item by selecting any cell in the desired row and entering **Load Selected**

Input Data for an Equipment Item stored in one row by Equipment Tag

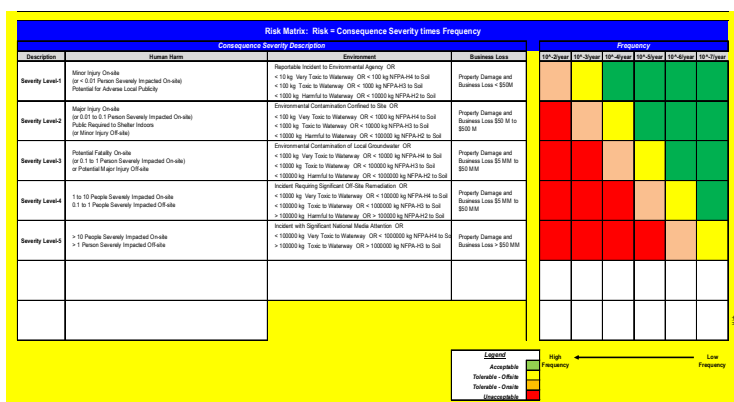
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Risk Analysis Screening Tools (RAST) Risk Matrix

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).



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Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – Chlorine Repackaging

Suggested Scenarios for Rail Car

Suggested Scenarios from the RAST Library

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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?

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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.

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Explosion Summary: VCE or Building Explosion Energy, kcal Maximum Distance to LFL Concentration, m Blast Overpressure at Center of Occupied Building 1, psi Distance to Severe Thermal Radiation Impact, m Rupture Explosion Energy, kcal Distance to Direct Blast Impact (10 psi), m Maximum Fragment Range, m Rupture Distance to 1 psi Overpressure, m Rupture Overpressure at Center of Occupied Building 1, psi Rupture Overpressure at Center of Occupied Building 2, psi		Probability of Ignition (POI) Probability of Explosion
Incident Outcome and Consequence Summary: Impact Assessment with Personnel routinely in the immediate area Offsite Toxic Impact based on Toxic Ingestion Method and 100 m to Fence Line with potential for 80.4 people severely impacted Onsite Toxic Impact based on Distance to LC50 Concentration of 80.3 m Outdoor Toxic Exposure Duration 600 sec Onsite Flash Fire Impact based on Distance to 0.5 LFL Concentration of 0 m Chemical Exposure based on Dermal or Thermal Hazards and Spray Distance of 14 m Equipment Failure Direct Blast Impact based on Distance to 10 psi Onsite Thermal Radiation Impact based on Distance from Fireball Number of Potential Severe Toxic Impacts Onsite: 16.9 people Number of Potential Severe Flash Fire/Fireball Impacts Onsite: 0 people		LOPA Tolerable Frequency Factors Based On Estimated Number of People Impacted Criteria Yes No NA
Occupied Building Toxic Impact 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 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 Physical Explosion Impact 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:		Yes No No No NA

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.

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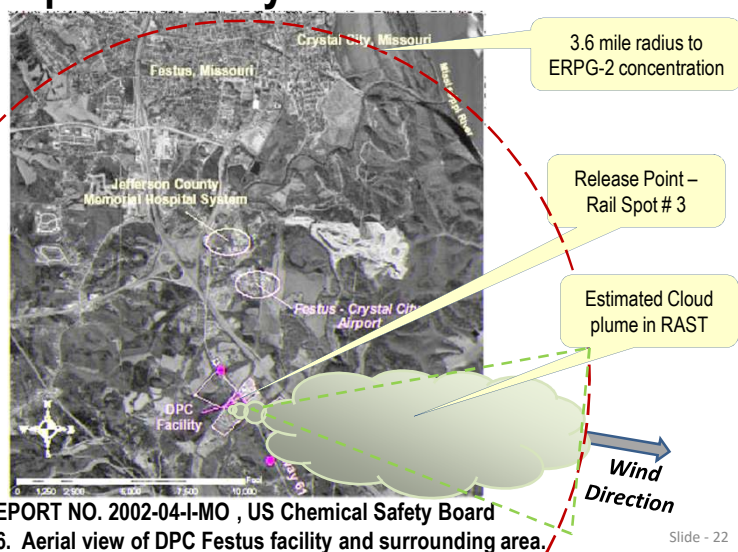
Case Study – Chlorine Repackaging Consequence Analysis

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.

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CPS
Center for Chemical Process Safety

Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – Chlorine Repackaging

Risk Analysis / Layers of Protection Analysis (LOPA)

Version: 2.0
Equipment Loaded: Chlorine Rail Car
Sort: Reset Filters
Create User Scenario: Modify Scenario
Duplicate Scenario: Risk Summary

LOPA Worksheet

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.	This incident could result in an Off-Site Toxic Release at a Distance to ERPG-2 Concentration (H2O) 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.			
Instrumented Protection Credits Taken	IPL Status? -->					
Safety Analysis		Tolerable Frequency Factor 6	Unloading/Loading Hose Failure	1	0	0

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ANACHE Technology Alliance
CPS
Center for Chemical Process Safety

Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – Chlorine Repackaging

Risk Analysis / Layers of Protection Analysis (LOPA)

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.	This incident could result in an Off-Site Toxic Release at a Distance to ERPG-2 Concentration (H2O) 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		IPL Status? -->					
Safety Analysis			Tolerable Frequency Factor 6	Unloading/Loading Hose Failure	1	0	0

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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								Notes / Comments	Issues to Resolve
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		
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 > 14 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 valves for both the BPCS and the SIL-2 SIS and not be sufficiently reliable. Finally, the Excess Flow Valve may not be effective as it addresses leaks less than 15000 lb/hour for which there remains a significant consequence severity.

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Risk Analysis Screening Tools (RAST)

Case Study – Chlorine Repackaging

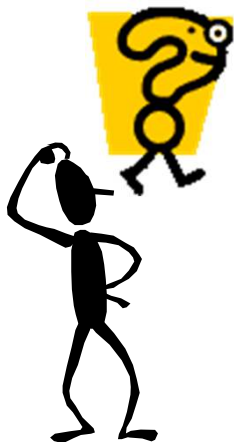
Risk Analysis and Incident Investigation often use similar methods to better understand the scenario. Risk Analysis “anticipates” what could go wrong and what the “worst” potential consequences may be. For Incident Investigation, the Incident Outcome and Consequences are known in addition to the actual 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 be much worse if wind and other conditions would have been different?”

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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)

A "Hazard Identification and Risk Analysis (HIRA)"

What can go Wrong?

How to Sustain?

What are the Hazards?

How Bad Could it Be?

Is the Risk Tolerable?

How Often Might it Happen?

Select
Equipment or
Activity to be
Analyzed

Identify
Chemical
and Process
Hazards

Develop
Scenarios

Analyze
Consequences

Estimate
Frequency

Analyze
Risk

Implement
Additional
Safeguards as
Needed

Sustain
Safeguards for
Life Cycle of
Facility

