Risk Analysis Screening Tools (RAST) Overview / Demonstration

Case Study – DPC Industries

DPC Enterprises – Chorine Release
Festus, Missouri
August 14, 2002
Case Study – DPC Industries

Hazard Identification and Risk Analysis (HIRA) Study

What are the Hazards? What can go Wrong? How Bad could it Be? How Often might it Happen? Is the Risk Tolerable?

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 – DPC Industries

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.
Case Study – DPC Industries

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 – DPC Industries

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 – DPC Industries

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) Overview / Demonstration

Risk Analysis Screening Tools (RAST) Case Study – DPC Instrustries

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

Enter Equipment Identification, Equipment Type and Location
Case Study – DPC Industries

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.
A chlorine rail car contains a maximum of 82000 kg chlorine (90 m³ or 17300 gal). The maximum allowable working pressure is 26 barg or 375 psig. Liquid connections are 1 inch.
Case Study – DPC Industries

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 – DPC Industries

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.
Case Study – DPC Industries

Site Layout

Examples of Sparsely populated areas

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.
Case Study – DPC Industries

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

Examples of Densely populated areas

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

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

Case Study – DPC Industries

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.
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 – DPC Industries
Suggested Scenarios for Rail Car

HAZOP Node: Plant Section = Equipment Type = Equipment Tag = Chlorine Rail Car

HAZOP Design Intent
Chlorine Rail Car is a Tank Truck/Rail Car/Tote containing Chlorine that operates at 25°C and 8 bar. The volume is 18000 gal with a maximum allowable working pressure of 375 psi. The maximum feed or flow rate is 0 kg/min.

LOPA Menu Filters:
Mechanical Integrity Scenarios will NOT be reported
Scenarios with NO IPL’s Required will NOT be reported.

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.

<table>
<thead>
<tr>
<th>Scenario Type</th>
<th>Scenario Comments</th>
<th>Parameters and Deviation</th>
<th>Initiating Event (Cause)</th>
<th>Initiating Event Description</th>
<th>Loss Event</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage from Movement</td>
<td>Spill caused by Truck or car movement while transfer is in progress</td>
<td>Flow-Loss of Containment</td>
<td>3rd Party Intervention</td>
<td>Driver inadvertently moves truck or car</td>
<td>Full Bore Hole Size Leak</td>
<td>Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration</td>
</tr>
<tr>
<td>Drain or Vent Valve Open</td>
<td>Drain or Vent Valve left open following loading/unloading or batch transfer</td>
<td>Flow-Loss of Containment</td>
<td>Human Failure Action more than once per quarter</td>
<td>Operator leaves Drain or Vent Open following unloading or clean-out</td>
<td>Drain or Vent Leak</td>
<td>Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration</td>
</tr>
<tr>
<td>Hose or Loading Arm Connection</td>
<td>Spill associated with improper connection of hose or loading arm</td>
<td>Flow-Loss of Containment</td>
<td>Human Failure Action more than once per quarter</td>
<td>Operator fails to ensure a proper connection before starting material transfer</td>
<td>Gasket Failure</td>
<td>Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration</td>
</tr>
<tr>
<td>Piping or Equipment Leak - Full Bore</td>
<td>Assessment Excludes Mechanical Integrity Scenarios</td>
<td>Flow-Loss of Containment</td>
<td>Unloading/Loading Hose Failure</td>
<td>Failure of Hose from fatigue, etc.</td>
<td>Full Bore Hole Size Leak</td>
<td>Off-Site Toxic Release, On-Site Toxic Release, Toxic Infiltration</td>
</tr>
<tr>
<td>Excessive Heat Input - Heat Transfer</td>
<td>No Heating Media Temperature was noted</td>
<td>Pressure-High</td>
<td>BPCS Instrument Loop Failure</td>
<td>Failure of Flow Control</td>
<td>Criteria for Triggering Incidents Not Met</td>
<td></td>
</tr>
<tr>
<td>Excessive Pad Gas Pressure</td>
<td>Maximum Pad Gas Pressure Does Not Exceed the Maximum Allowable Working Pressure or Relief Set Pressure</td>
<td>Flow-High</td>
<td>Regulator Failure</td>
<td>Regulator Fails causing high flow or pressure</td>
<td>Criteria for Triggering Incidents Not Met</td>
<td></td>
</tr>
<tr>
<td>Overfill, Overflow, or Backflow</td>
<td>Overfill or Backflow of liquid with spill rate equal to the feed rate to a maximum quantity of the available inventory minus contained mass</td>
<td>Level-High or Flow-Backflow</td>
<td>BPCS Instrument Loop Failure</td>
<td>Failure of Level Indication with continued addition of material</td>
<td>Criteria for Triggering Incidents Not Met</td>
<td></td>
</tr>
<tr>
<td>Pad Gas Compression</td>
<td>Maximum Feed or Downstream Pressure does not exceed the Maximum Allowable Working Pressure or Relief Set Pressure</td>
<td>Pressure-High</td>
<td>BPCS Instrument Loop Failure</td>
<td>Failure of Pressure Control</td>
<td>Criteria for Triggering Incidents Not Met</td>
<td></td>
</tr>
<tr>
<td>Vacuum Damage</td>
<td>Equipment is rated for Full Vacuum</td>
<td>Pressure-Low</td>
<td>Human Failure Action more than once per quarter</td>
<td>Operator leaves valves closed allowing vacuum during emptying of equipment</td>
<td>Criteria for Triggering Incidents Not Met</td>
<td></td>
</tr>
</tbody>
</table>

Potential Outcome / Tolerable Frequency Factors

Off-Site Toxic Release
On-Site Toxic Release
Indoor Toxic Release
Flash Fire or Fireball
Vapor Cloud Explosion
Building Explosion
Equipment Explosion
Property Damage or Business Loss
Environmental Damage

Potential Scenarios in gray were considered but are excluded for reason noted.
Case Study – DPC Industries
Suggested Scenarios for the Rail Car

- Review the suggested list of scenarios. Do these represent what you would expect for a rail car 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 – DPC Industries
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 more than 3400 m or 2.1 miles. Adjusting for the actual 1.5 m/sec wind speed at the time of the incident, the distance to ERPG-2 would have been estimated at 3.0 miles which is in close agreement with CPB modeling of 3.7 miles.

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

The actual wind speed was nearly 1.5 m/sec. Wind speed, atmospheric stability, and surface roughness are Administrative Parameters that may be adjusted on hidden worksheets.
Case Study – DPC Industries

Consequence Analysis

The estimated number of severely impacted people (potential fatalities) is greater than 10 for either the offsite occupied businesses or the trailer park. Fortunately the wind was away from the trailer park (and most residents were at work rather than home) and personnel within the site office and nearby occupied buildings 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 number of people severely impacted is highly inaccurate and represents a “worst” case assuming no effective evasive actions or effective safeguards.

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

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.
Case Study – DPC Industries

Risk Analysis / Layers of Protection Analysis (LOPA)

A time at risk enabling condition of the leak occurring only during a 2000 hour operation per 8760 hour year may be appropriate as 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 – DPC Industries

Risk Analysis / Layers of Protection Analysis (LOPA)

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 and Incident Investigation often use similar methods to better understand the scenario. Risk Analysis “anticipates” what could go wrong and what the 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. However, the “order of magnitude” estimate of consequences seems reasonable.
Questions?