

Refrigeration System Ammonia Leaks: Understanding and Preventing Common Failures

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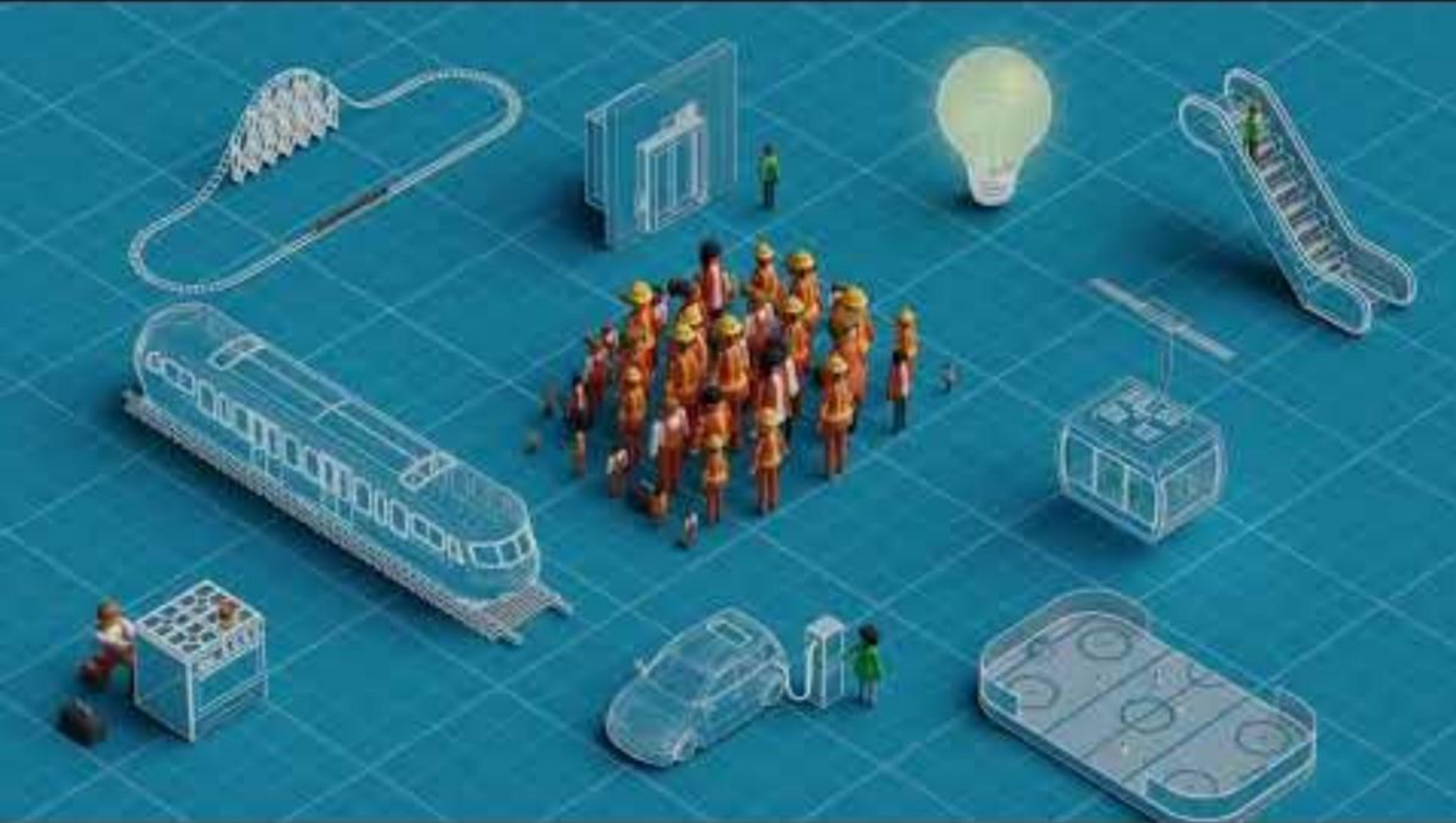
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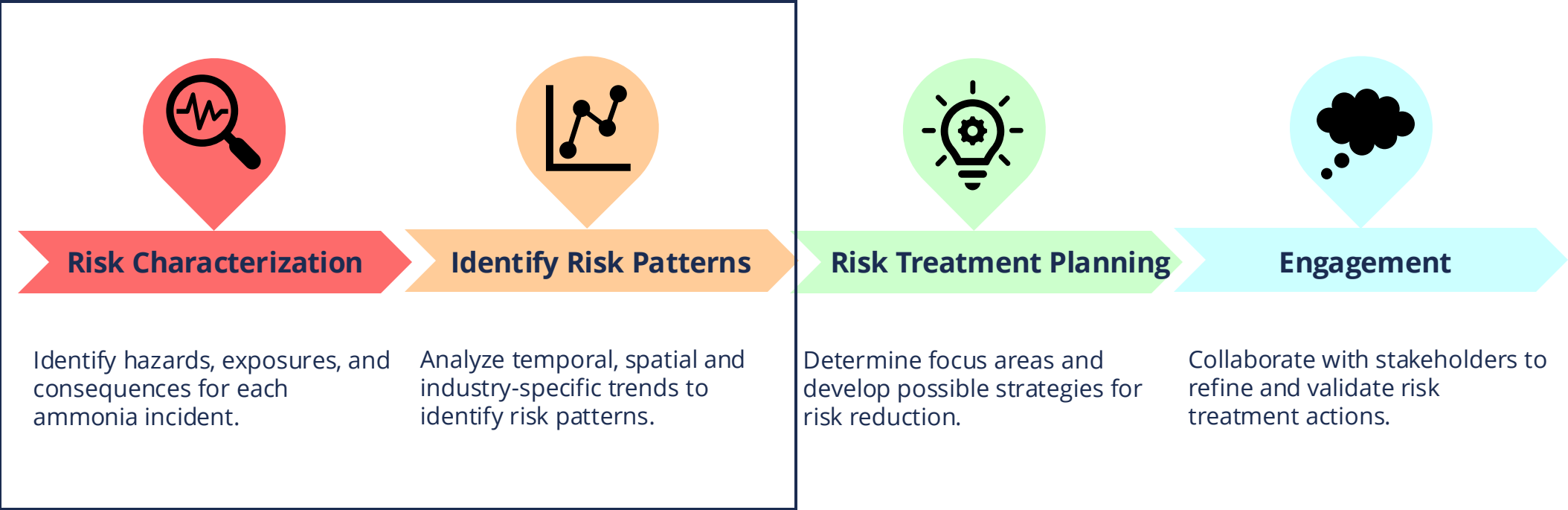
Agenda

- Ammonia Risk Analysis
 - Objectives and Methods
 - Results
- Preliminary Risk Treatment Options
 - Your Feedback
- Q&A



Overview

RISK ANALYSIS



Objectives – Why are we doing this risk analysis?

To understand:

- *How do ammonia leaks happen and what are the causal factors?*
- *Where do they happen and who is exposed?*
- *What prominent scenarios and patterns are there?*

The findings will shape risk treatment actions to be implemented by TSBC

Risk Components

Consequence

The effect of being exposed to the hazard (e.g. injury, fatality, damage, societal implications, etc.)



Hazard

A source of potential harm to persons or damage to property or equipment



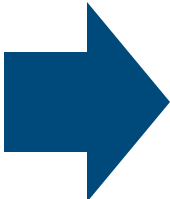
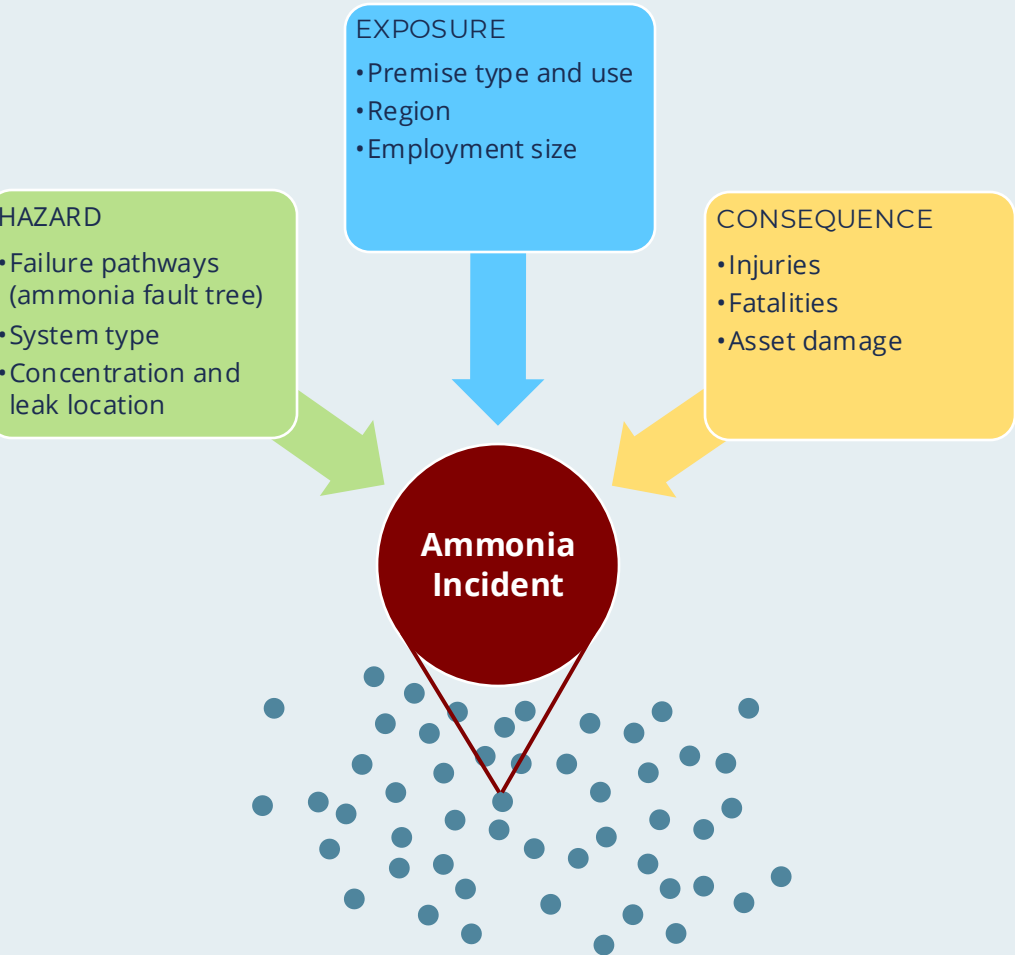
Exposure

The extent/amount of people or property subject to a hazard

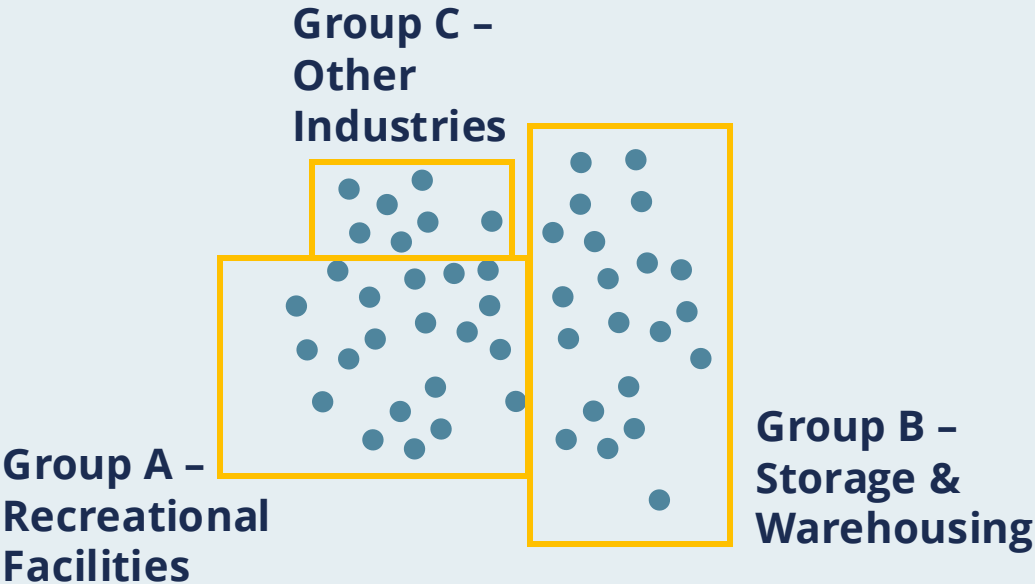


Risk Analysis Approach

Characterizing hazard, exposure and consequence of each incident



Grouping incidents by sectors and analyze similarities and differences

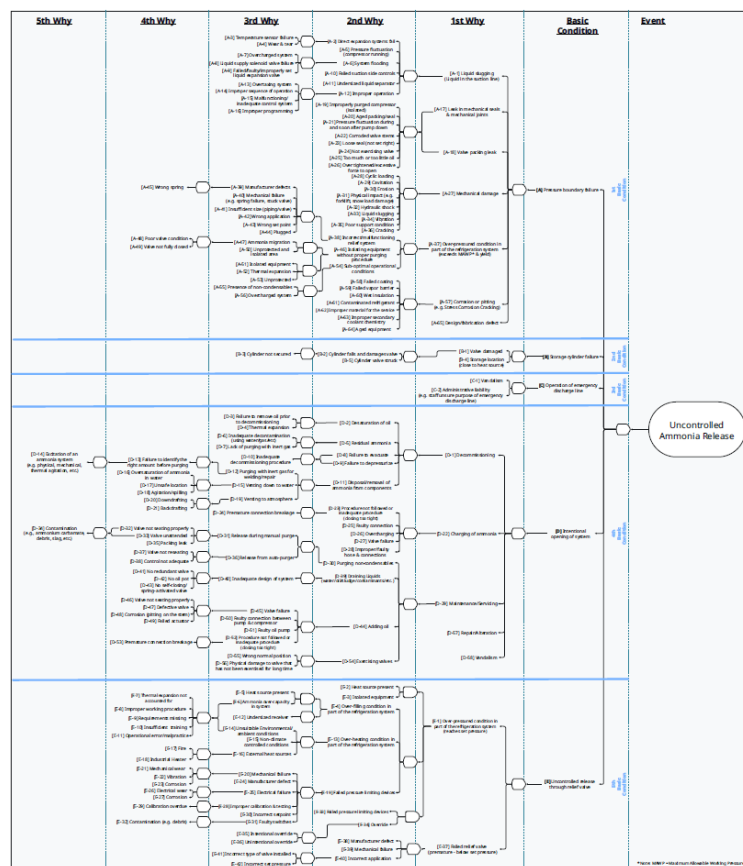


Understanding ammonia incidents in different sectors to develop more relevant risk treatment actions

Risk Characteristics and Patterns in BC



Identifying failure pathways (Fault Tree)

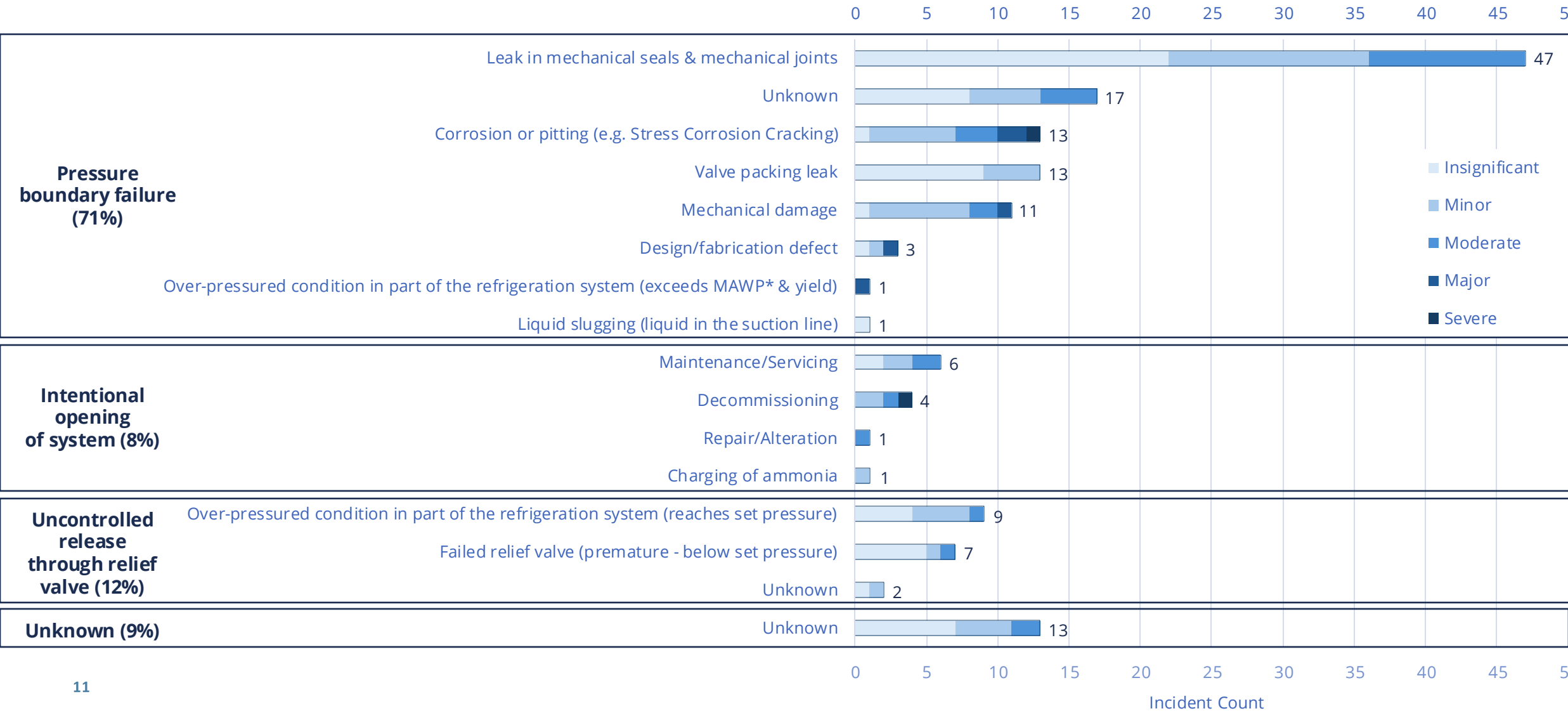


- Fault tree developed in 2025
- Engaged 250+ refrigeration system owners, contractors, power engineers to review draft
- Feedback received via online survey and a virtual workshop

Scan to download the ammonia fault tree!



What failure pathways results in ammonia incidents?



*MAWP = Maximum Allowable Working Pressure

What is the concentration of ammonia at these incidents?

- Median = 68 ppm, Range: 3 – 20000 ppm
- 15 incidents reported immediately dangerous to life and health concentrations

Basic Condition	Pressure Boundary Failure	Intentional Opening of System	Uncontrolled Release Through Relief Valve
Incidents	44	3	6
Range (ppm)	3-20000	25-499	35-10000
Median (ppm)	65	48	2750

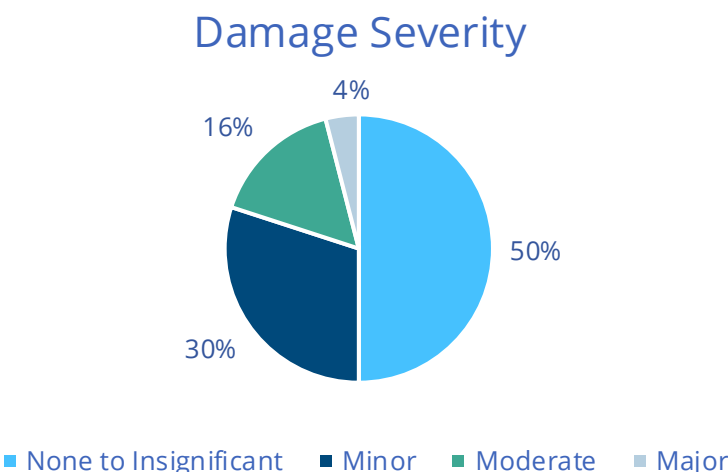
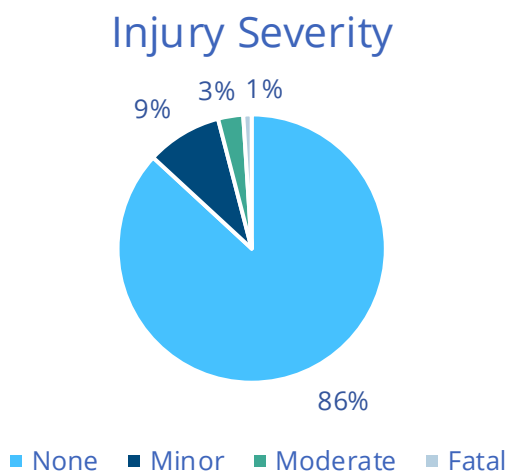
Note: Concentrations were reported in 56 incidents (38% of the dataset).



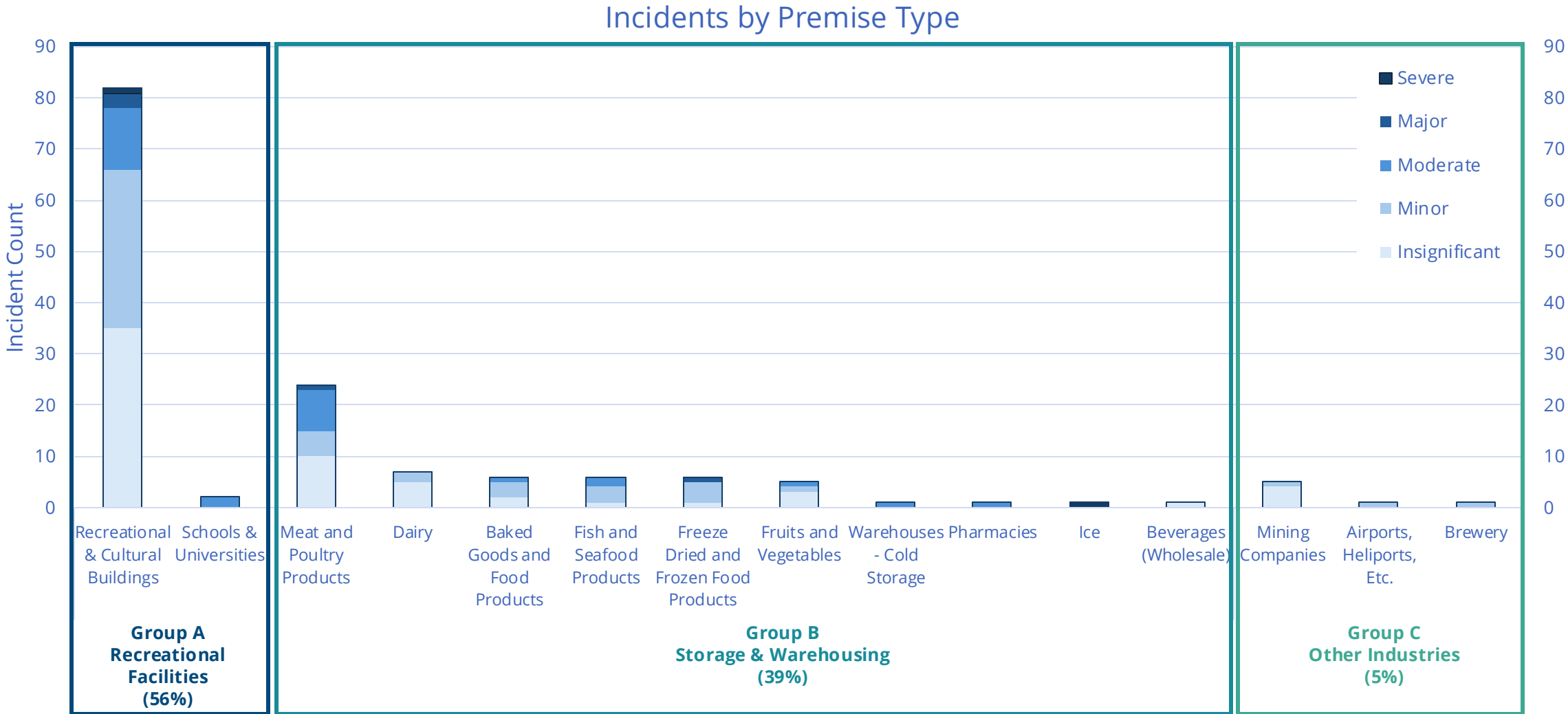
What kind of injuries or damages resulted from ammonia incidents?

Of 149 reported ammonia incidents between 2008 and 2024,

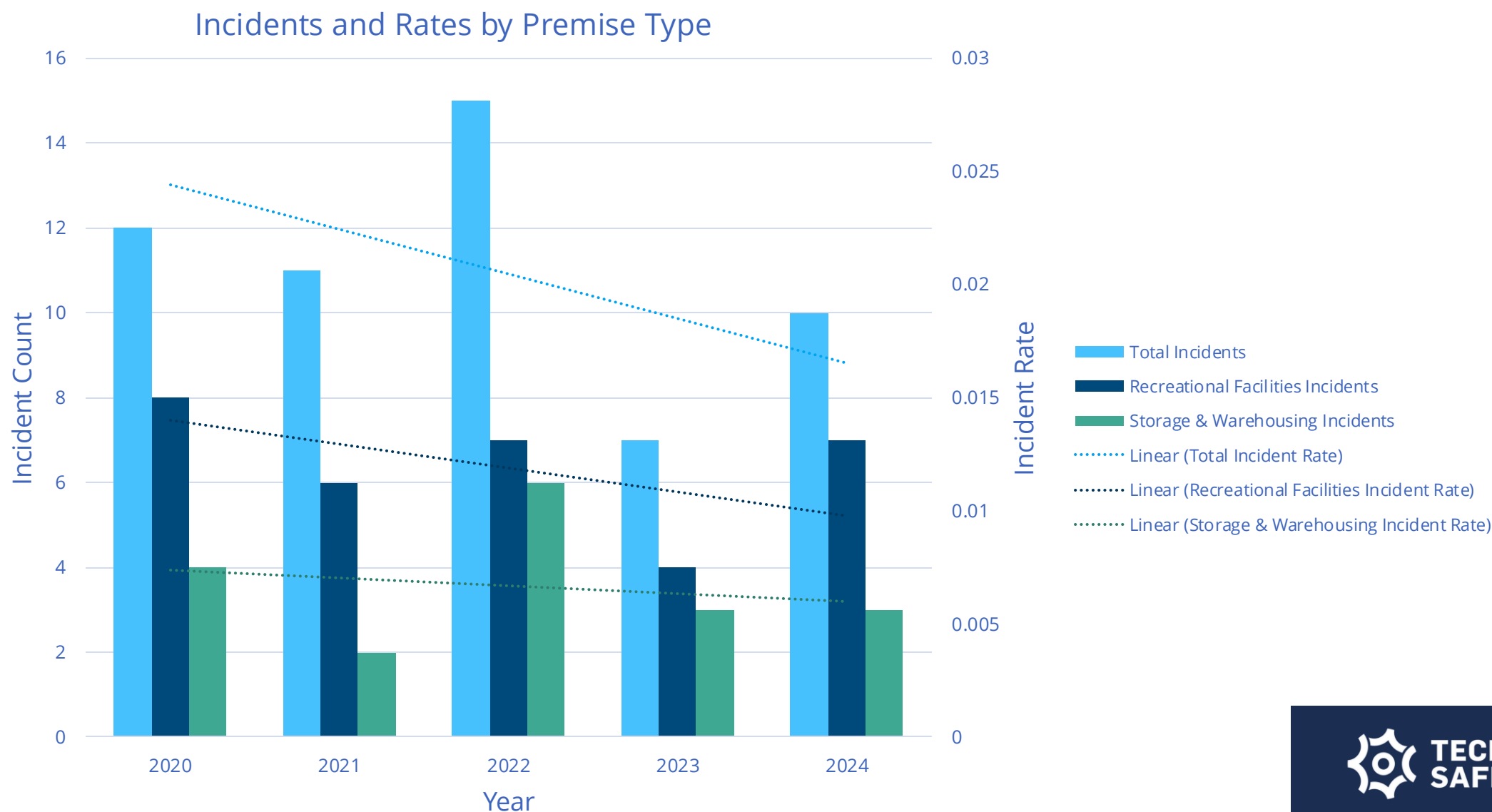
- 18 incidents (12%) led to a total of 56 injuries (0.38 injuries/incident)
- 2 incidents (1%) led to a total of 4 fatalities (0.03 fatalities/incident)



What sectors are incidents happening at?

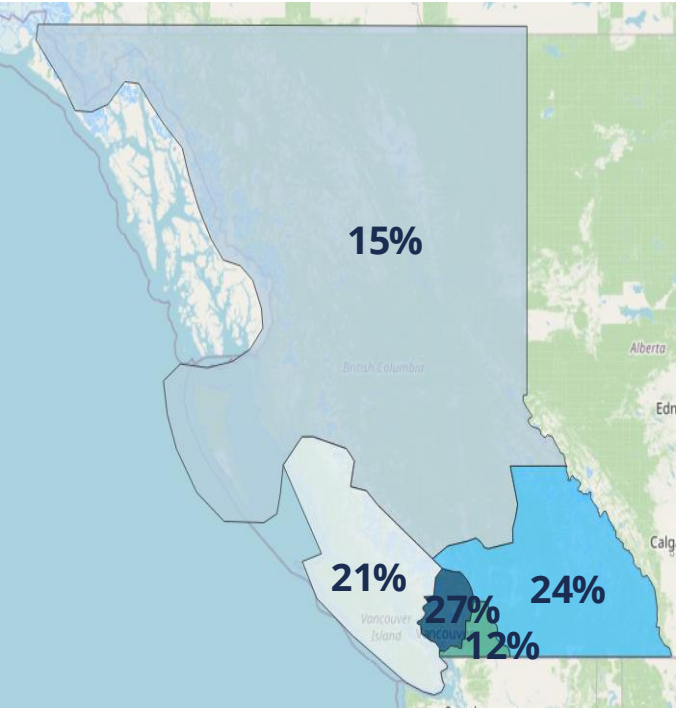


How often does ammonia incidents happen each year?

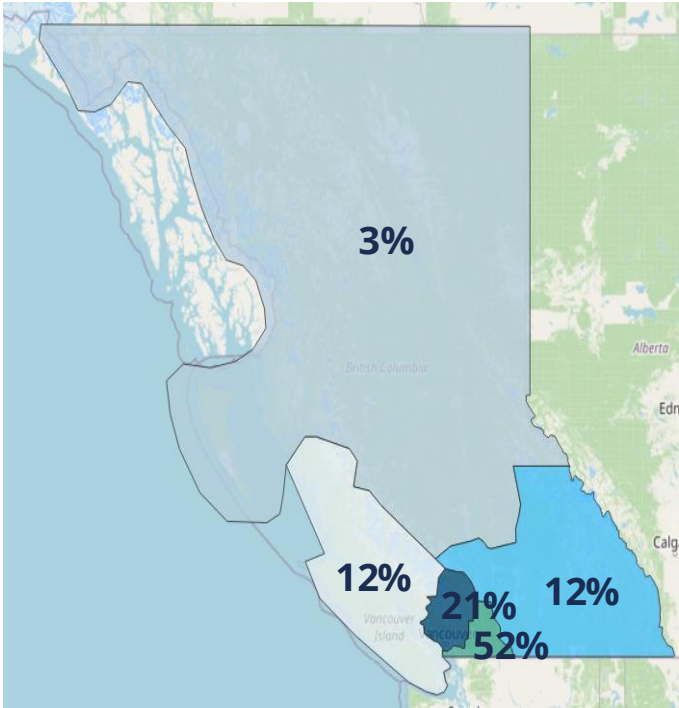


Does it vary across the regions?

Recreational Facilities



Storage & Warehousing



■ Interior ■ Lower Mainland North ■ Lower Mainland South ■ Northern ■ Vancouver Island

Region	Recreational Facilities		Storage & Warehousing	
	5 Yr Avg Incident Rate per 10,000	5 Yr Avg Injury Rate per 10,000	5 Yr Avg Incident Rate per 10,000	5 Yr Avg Injury Rate per 10,000
Interior	0.024	0	0.007	0
Lower Mainland North	0.011	0.014	0.002	0
Lower Mainland South	0.005	0	0.017	0.003
Northern	0.024	0	0	0
Vancouver Island	0.009	0	0.004	0.002

Key characteristics of incidents by sectors

Group A
Recreational Facilities
n=84 (56%)



Group B
Storage & Warehousing
n=58 (39%)



Group C
Other Industries
n=7 (5%)



HAZARD

- ☐ Pressure boundary failures
- ☐ Intentional opening of system
- ☐ Uncontrolled release through relief valve
- ☐ Indirect Closed Surface Systems
- ☐ Median: 62 ppm (Range: 3-20000) Machinery Room or Outdoors

- ☐ Similar to Group A, with **more leaks in mechanical seals/joints and fewer valve packing leaks**
- ☐ Direct Systems
- ☐ Median: **154** ppm (Range: 10-5000) Machinery Room/Refrigerated Room or Outdoors

- ☐ Pressure boundary failures
- ☐ N/A
- ☐ No reported concentrations All Indoors

EXPOSURE

- ☐ Regionally distributed
- ☐ Small employers
- ☐ **Public and workforce exposures**

- ☐ **LMS (52%), LMN (21%)**
- ☐ Large employers with few med/small employers (Workforce exposures)

- ☐ Interior, VI, Northern
- ☐ Large employers
- ☐ Mostly workforce exposures

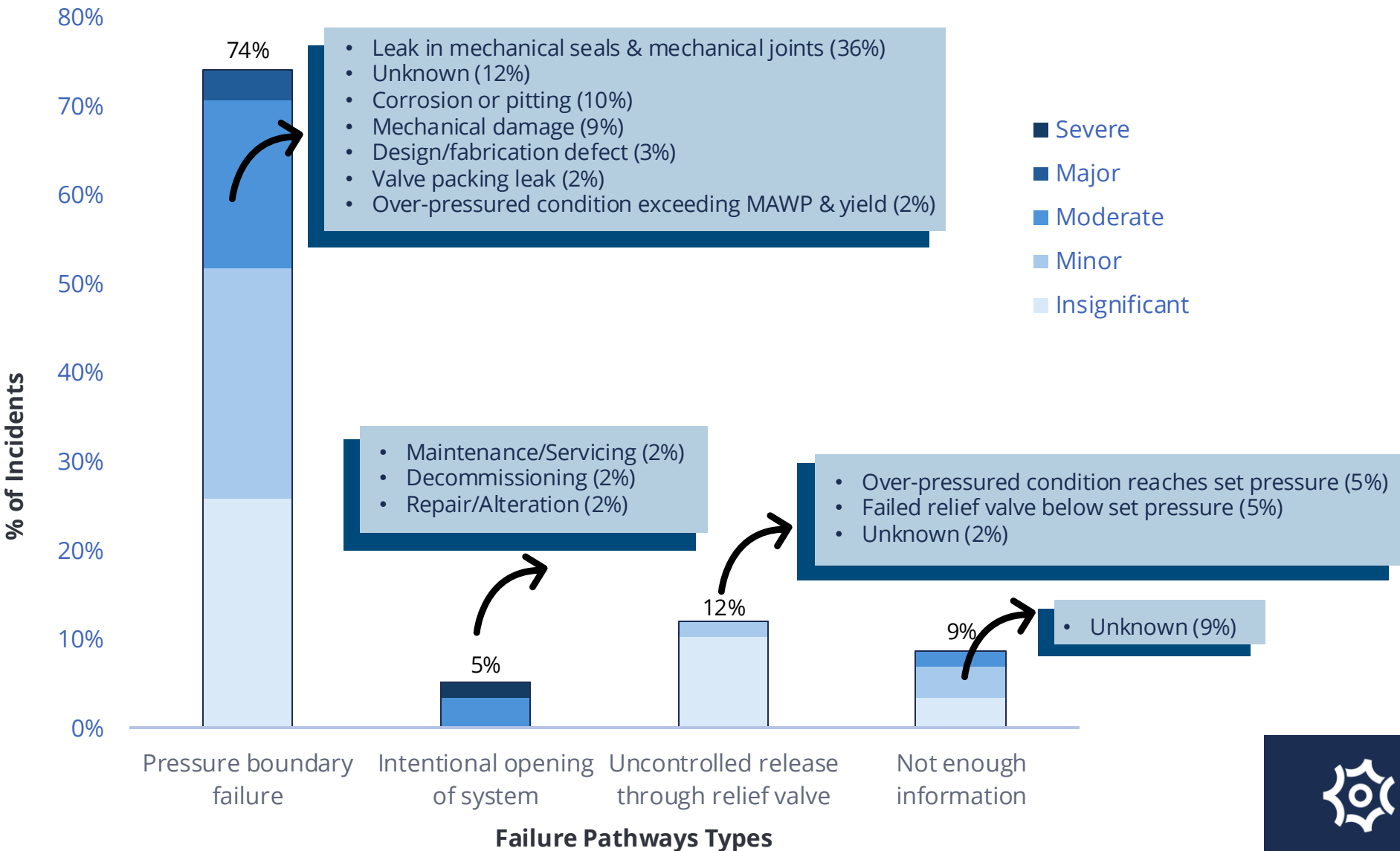
CONSEQUENCE

- ☐ 3 fatalities
- ☐ 30 injuries

- ☐ 1 fatality
- ☐ 26 injuries

- ☐ No fatalities
- ☐ No injuries

Failure scenarios of incidents at storage & warehousing facilities



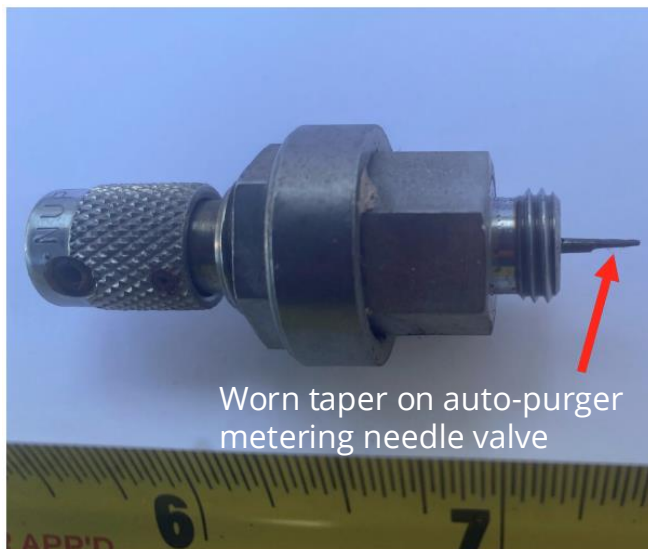
Critical Incidents – Fatality

In 2022, at an industrial ice-making facility in Interior BC, a crew was in the process of disassembling two ammonia refrigeration systems and was working with the understanding that ammonia had been safely removed. A ball valve was opened which released a large ammonia cloud that contacted a source of ignition and ignited. This incident resulted in a fatality, multiple exposures, a local evacuation, an extended business shutdown and an environmental response.



Critical Incidents – Chemical Burns

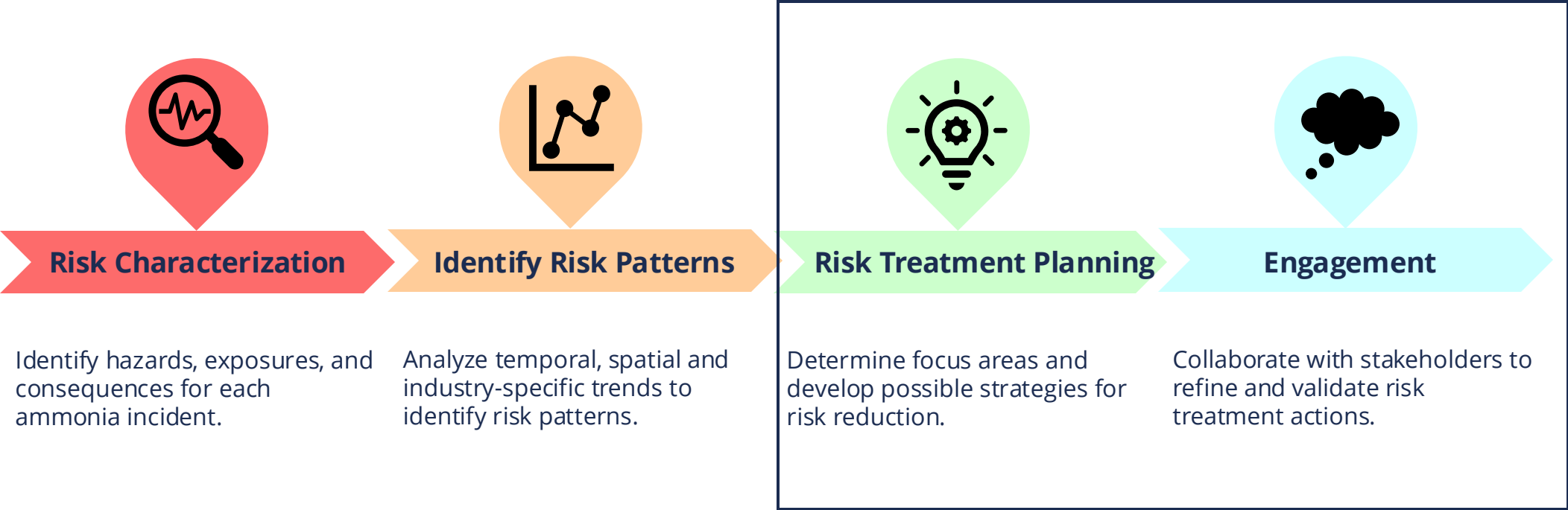
In 2021, approximately 6.7 lbs of ammonia leaked from a food processing facility's auto-purger into the mechanical room. The cause was likely the extended operation of this auto-purger well past its maximum expected lifecycle of 20 years without routine inspection and maintenance. While attempting to isolate and shut-off the equipment, the liquid in the bubbler tube sprayed out and caused chemical burns to their head, ear, neck and upper chest. A refrigeration contractor technician subsequently received burns to their forearm and bicep.



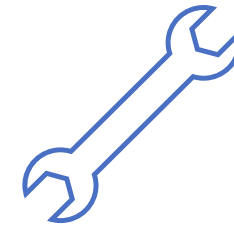
Risk Treatment and Engagement



Overview



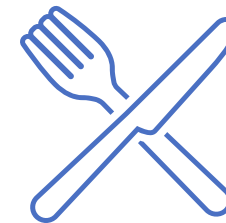
Preliminary Risk Treatment Ideas



Promote Regular
Maintenance



Protect Integrity
of Safety Features



Storage & Warehousing
Sector

Poll Question #1

What is your role in your organization?

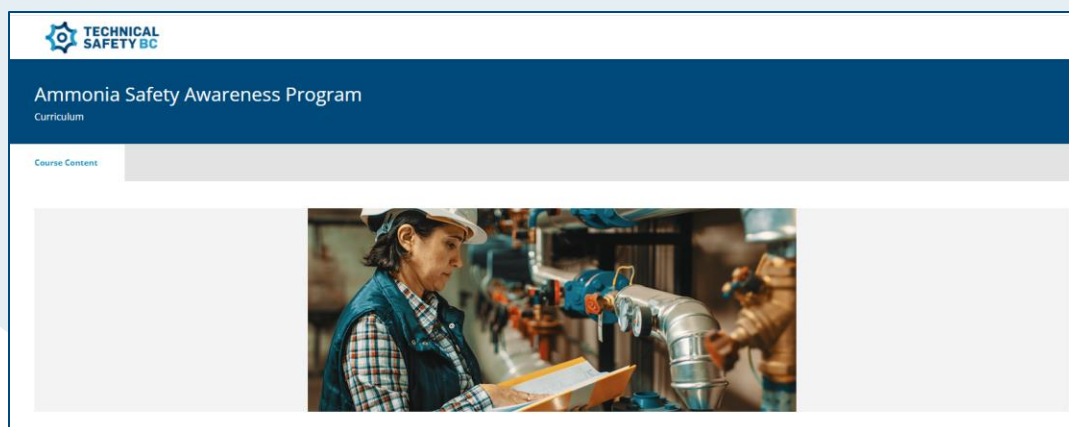
- ☐ Owner
- ☐ Manager/Supervisor
- ☐ Operator with Refrigeration Operator Certificate of Qualification
- ☐ Operator with 4th Class or Higher Power Engineer Certificate of Qualification
- ☐ Contractor
- ☐ Health and Safety Professional
- ☐ Joint Occupational Health and Safety Committee Member
- ☐ Other

Option 1: New Education Program for Owners/Managers

WHY?

Empower owners/managers to:

- Proactively **plan and budget for repairs and maintenance** to minimize leaks and service disruptions
- Prevent operational delays and reduce risk to workers and the public



WHAT?

Short education e-learning program (hosted by TSBC) to provide owners/managers with a single point of access to information on:

- ✓ Legal responsibilities
- ✓ When and how to involve TSBC
- ✓ What kind of repairs and maintenance are required at what frequency

Poll Question #2

What does your facility's preventative maintenance program include? Select all that apply.

- ☐ Equipment inventory
- ☐ Periodic testing requirements
- ☐ Periodic inspections
- ☐ Logbooks for maintenance activities
- ☐ Standard operating procedures for maintenance tasks
- ☐ I am not sure.
- ☐ We do not have a structured maintenance program.

Option 2: Mandatory Preventative Maintenance Program

WHY?

- Strengthen and standardize preventative maintenance practices
- Address common failure scenarios linked to inadequate maintenance
- Centralize regulatory testing and inspection requirements

WHAT?

Each site to develop a **site-specific** preventative maintenance program including inspection and maintenance:

- ✓ Checklists
- ✓ Logbooks
- ✓ SOPs
- ✓ Equipment Inventory

TSBC support through:

- Phase-in requirement
- Tools and resources for equipment management
- Partner with Safety Officers

Poll Question #3

Which of the following are barriers to performing regular preventative maintenance? Select all that apply.

- ☐ Inadequate budget for maintenance activities
- ☐ Lack of a documented maintenance plan or schedule
- ☐ Lack of support from management
- ☐ Lack of, or limited access to, qualified individuals
- ☐ Lack of knowledge of maintenance requirements
- ☐ Lack of knowledge of how to conduct maintenance
- ☐ Lack of knowledge of required maintenance frequency

Option 3: Communication Campaign on Tips to Avoid Safety Overrides

WHY?

- To prevent failures of the last line of defense by avoiding safety overrides
- Prevent uncontrolled release through relief valve incidents

WHAT?

TSBC to run outreach and awareness campaign to avoid safety overrides:

- ✓ How to recognize early warnings signs (nuisance tripping)
- ✓ Severity of consequences from temporary fixes and operating with an inactive safety feature

Poll Question #4

Which of the following situations do you think commonly lead to overriding a safety feature on an ammonia refrigeration system?

- ☐ Repeated tripping of safeties
- ☐ Production line pressure/losing ice
- ☐ Nuisance calls
- ☐ Other

Next Steps for Engagement

- Small group engagement with industry stakeholders
- Refine and update risk treatment actions
- Use QR code below to sign up for further engagement



Thank you!

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