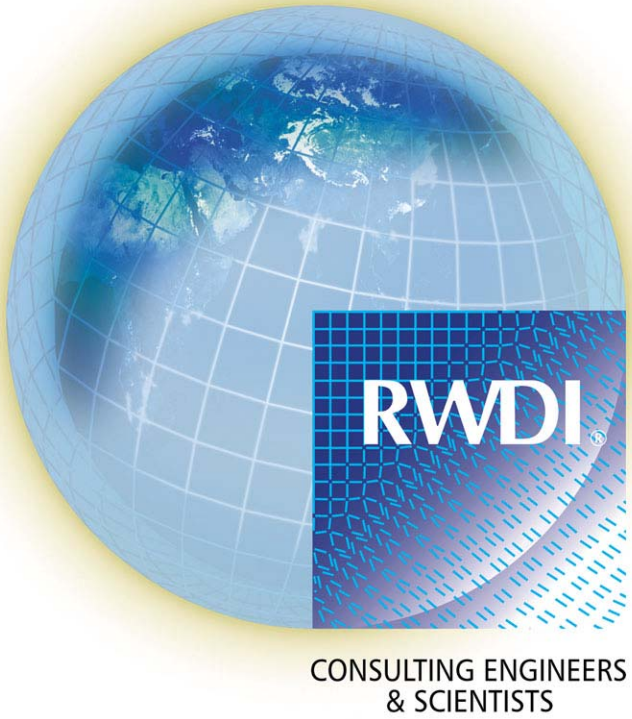
REPUTATION RESOURCES RESULTS




# Worst Case Scenario

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# Objectives of Session

This session will explore the concept of worst-case scenarios as applied to estimation of hazard and risk.

- The term ‘worst-case’ seems self-explanatory, but it meaning is often unclear
- Since the ‘worst-case’ concept is an integral part of risk management and emergency planning, clear understanding of worst-case terminology and events is vital

# ‘Worst-Case’ Events

Accident

- an event that causes damage, injury or death

Disaster

- an accident that causes great distress or destruction

Catastrophe

- a momentous tragic event ranging from extreme misfortune to utter ruin”

What is the difference?

Difference between accident and disaster is the amount of damage or number of people involved

A catastrophe occurs when the resources required to address a disaster are overwhelmed

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# Ammonium Nitrate Explosion

## Texas City, Texas – April 16, 1947

Source: Fire Prevention And Engineering Bureau Of Texas

An explosion occurred on the ship S. S. GRANDCAMP during loading of ammonium nitrate. The accident damaged more than 90% of the city's buildings and killed nearly 600 people.

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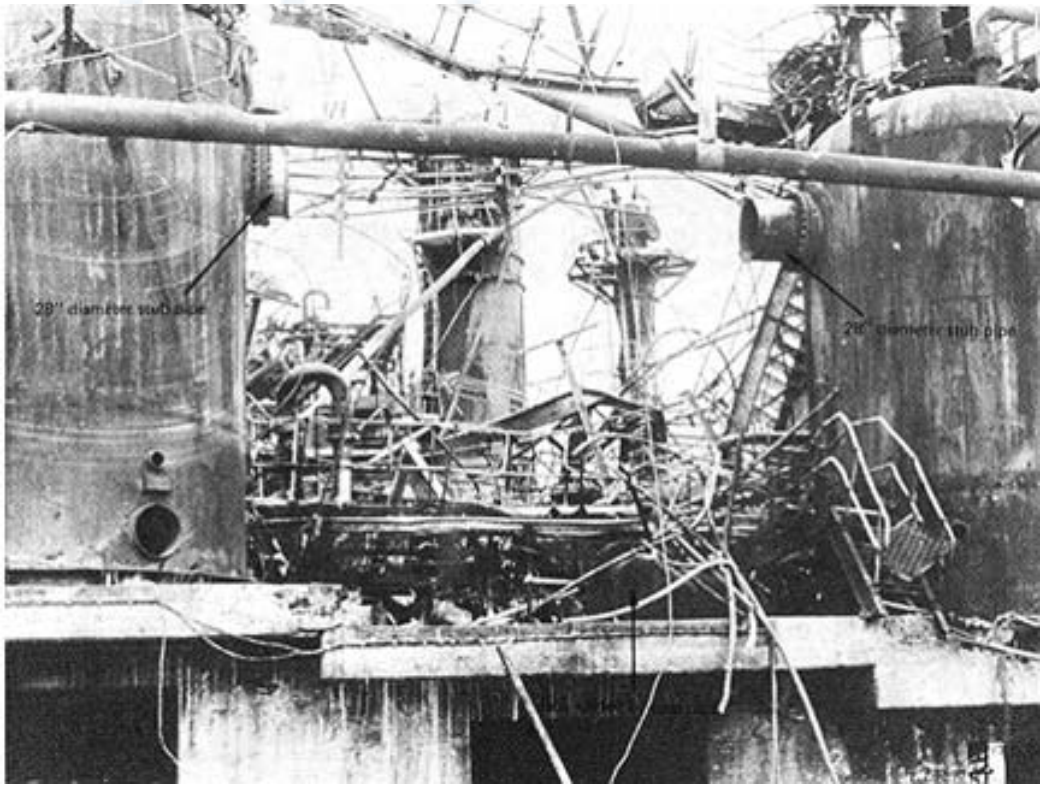
# Cyclohexane Release/Explosion

## Flixborough, England – June 1, 1974



Source: UK Health and Safety Executive, Hazardous Installations Directorate

A cyclohexane pipeline at the Nypro site ruptured, causing a large explosion. 28 workers were killed and a further 36 suffered injuries. Offsite consequences resulted in 53 reported injuries and significant property damage.

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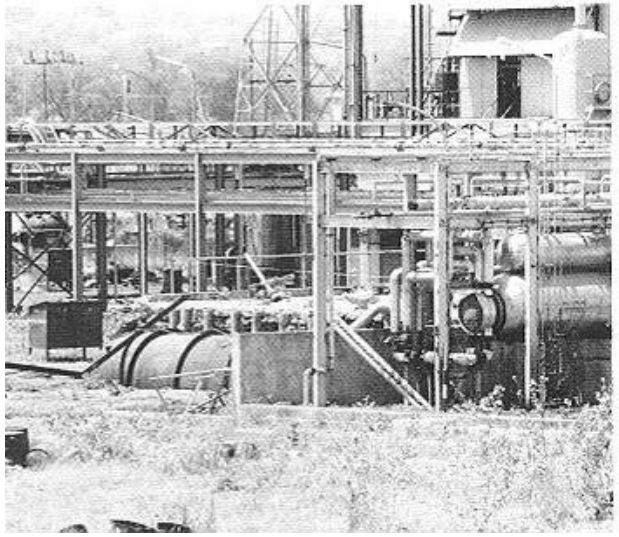
# Tank Rupture and Release

## Bhopal, India – Dec. 2-3, 1984

Source: United Nations Environment Programme



Water entered tank 610 in foreground of picture reacting with MIC and caused an uncontrolled release of a vapor cloud.

**A sudden release of methyl isocyanate (MIC) at the Union Carbide pesticide plant at Bhopal, India, led to the death of 2,800 – 8,000 people and caused respiratory damage and eye damage to over 20,000 others. Estimates of the damage vary widely between $350 million to as high as $3 billion.**

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# BP Refinery Explosion

## Texas City, Texas – March 23, 2005


Source: Texas City Explosion: 2005 Houston Chronicle Special Report

The chemical accident initiated in a raffinate splitter tower and associated blowdown system, causing an explosion that resulted in 15 deaths, 170 injuries and significant economic losses.

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Even in these cases, most people agree that the consequences of the events could have been worse…

…it is obvious that defining a worst case is not straight forward.

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# Definition of 'Worst Case'

- EPA
  - semi quantitative term
  - maximum possible exposure, dose, or risk
  - can conceivably occur, whether or not it actually occurs
- MIACC/CSChE
  - worst credible case
  - most probable release (risk)

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# Why Worst Case Analysis?

- Used when there is:
  - a number of potential outcomes
  - need to understand ‘how bad it could get’
- Applied to a variety of possible fields
  - financial, medical, environmental, recreational

# Canadian Regulatory Setting

Emergency plans required under the Canadian Environmental Protection Act must address the potential consequences of a release…

… where consequences are identified by consideration of ‘worst-case’ and ‘alternate’ scenarios

(Implementation Guidelines, CEPA 1999)

# USA Regulatory Setting

All companies using, manufacturing or storing hazardous materials must assess and divulge potential ‘worst-case’ release scenarios

(40 CFR 68)

…in light of recent focus on terrorism, worst case discussions have been removed from the public domain (www)

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# Use of 'Worst Case' Analysis

- Worst case analysis should be used to evaluate and enlighten, not frighten
- Seeks to understand
  - nature and extent of potential incident,
  - area and development of incident as defined by specified criteria
- Primary objective
  - prevention and planning

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# Prevention and Planning

## To prevent:

- Must understand how incidents could occur
- Use safety reviews, checklist analysis, FMEA - failure modes and effects analysis, HAZOP - hazard and operability analysis

## To plan:

- Must understand what incidents could occur
- Leads to need to understand ‘worst case’ event

Hazard analysis ➔ emergency planning (EPZ)

Risk analysis ➔ land use planning (setbacks)

# Hazard Evaluation Endpoints

- Different decisions require evaluation using different endpoints
  - for hazard evaluation, we consider acute, short-term effects (but this may be changing…)
- Generally, we want to know:
  - the highest potential 'cost' of incident, in terms of loss of life, injury, environmental and property damage,
  - the appropriate response or mitigation efforts,
  - the resources (personnel, equipment) required, and
  - the training necessary.

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# Importance of 'Getting It Right"

- Resources are limited, we must:
  - deploy appropriate response (people, equipment)
  - act within the appropriate timeframe
  - notify appropriate people, agencies
  - educate the appropriate people
- Pitfalls
  - Overestimation of hazard:
    - complacency,
    - cost,
    - fear factor.
  - Underestimation of hazard:
    - resources not available,
    - 'at risk' population not informed/notified,
    - catastrophe.

# Determination of Worst Case

How is ‘worst case’ release determined?

- by definition (see EPA)
- by consideration of a variety of potential or probable scenarios (see MIACC)
  - can use results of HAZOP studies to identify release scenarios
  - in some cases, worst-case release is not intuitive

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# Factors Affecting Release

- Fixed/given parameters
  - toxicity/flammability
  - composition
  - construction of vessel, pipeline, borehole
- Variable parameters
  - operating parameters
  - quantity of release*
  - rate of release*
  - meteorological condition

*highly dependant on scenario assumptions

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# Variable Parameters

- There is a need to determine which set / combination of variable parameters give rise to 'worst-case' release
- In hazard assessments, there is no consideration of probability; it is assumed that the 'worst case' conditions exist
- In risk assessments, probability weights the evaluation

*Risk = severity of consequence x frequency*

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# Worst Case Releases

- Quantity
  - mass released prior to engineered mitigative measures (*e.g.,* ESDs)
- Rate
  - for gases, total volume of vessel or pipeline segment in specified time period
  - for liquids, volatilization rate

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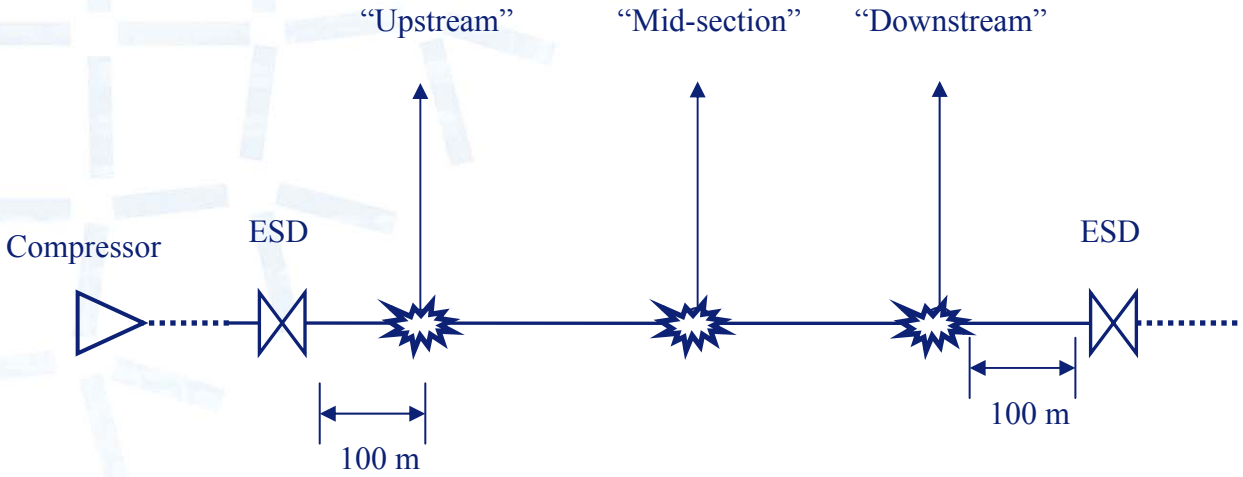
# Worst Case Meteorology

- Meteorological condition at the time of release is primary determinant of transport and dispersion of release
- Minimum dispersion generally occurs during stable, low wind conditions
- There are varying opinions regarding which stability class and wind speed to include:
  - EPA – F1.5
  - AEUB – F1
  - MIACC (based on TNO, “Dutch Guide”) – D5
  - CSChE – D5, F1.5

# Pipeline Releases




Which scenario will lead to worst case release?

- Pipeline rupture - complete severing of line, leading to 2 full cross-sectional areas for release
- Pipeline leak - smaller hole in line that may continue for a longer period of time undetected

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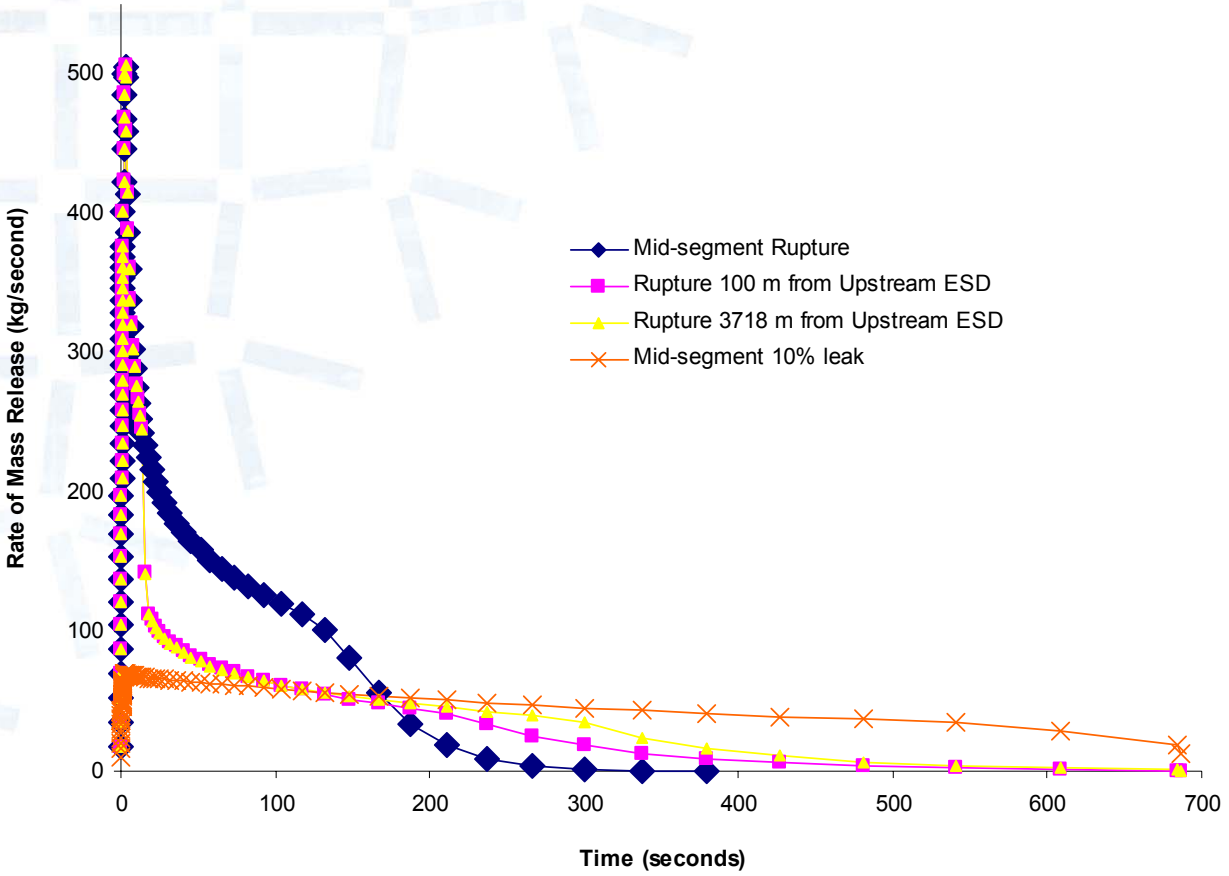
# Pipeline Release Profiles




When the rates of mass released during upstream, downstream and mid-segment ruptures are compared with a mid-segment 10% leak scenario, it is apparent that the leak scenario could result in a higher TWA exposure to the public.

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# Pipeline Release Statistics

| Release | Total Mass Released (tonnes) | Duration of Release (seconds) | Time to Trigger Upstream ESD (seconds) | Time to Trigger Downstream ESD (seconds) |
|---|---|---|---|---|
| Upstream | 22 | 338 | 15 | 205 |
| Mid-segment | 27 | 211 | 153 | 122 |
| Downstream | 25 | 427 | 276 | 15 |
| 10% Leak | 34 | 1466 | 593 | 557 |

Note that the leak case results in a higher total mass release, due to the delay in closure of the ESDs.

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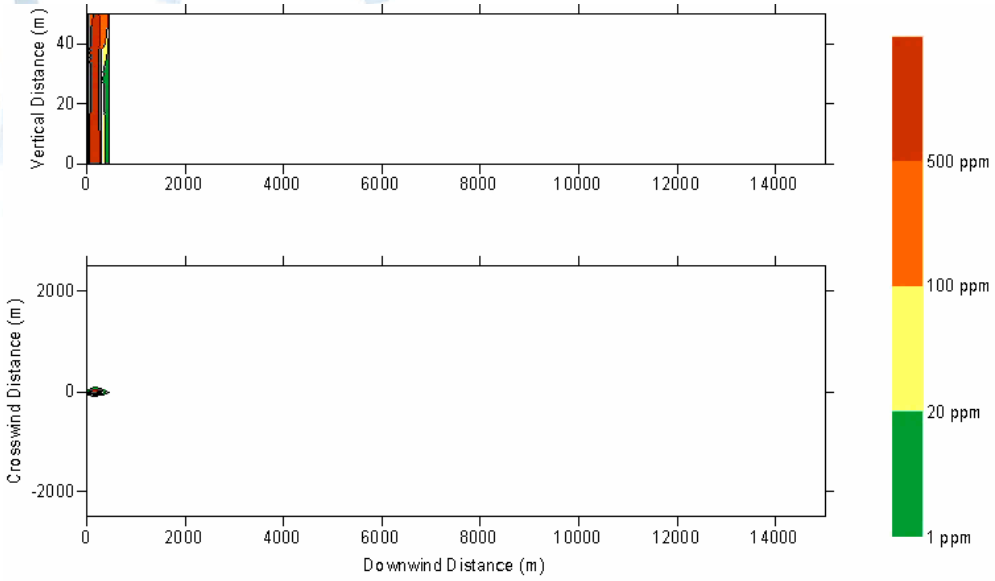
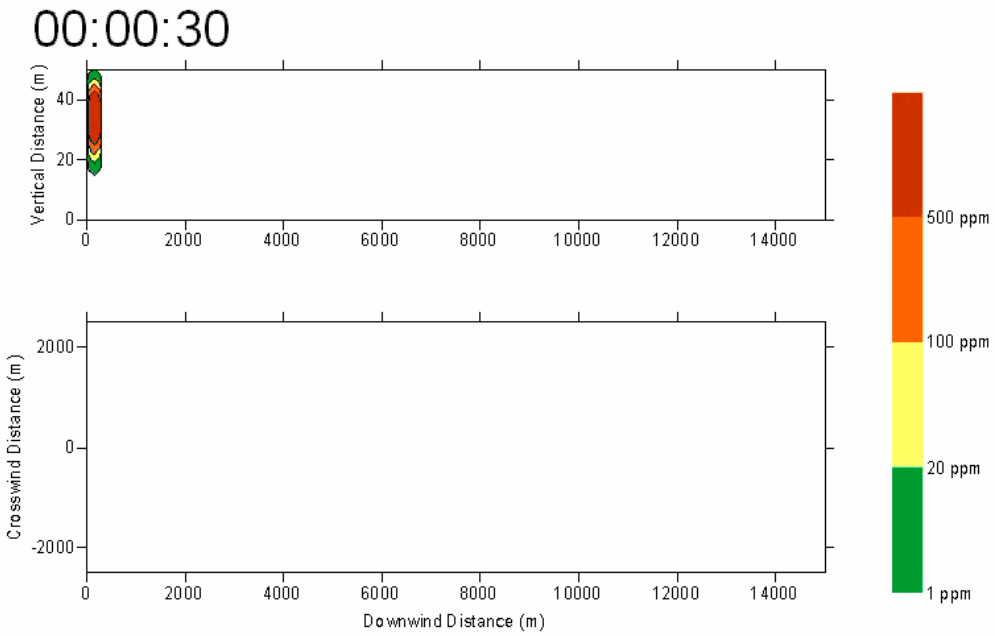
# Pipeline Illustration

These animations show the vertical and horizontal development of plumes from a pipeline rupture (top) and a pipeline leak (bottom). Note that $H_2S$ concentrations are initially higher for the rupture, but persist longer in the leak case.



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# Summary

- Worst-case scenario dependent on:
  - Endpoint criteria
  - Operating parameters
  - Release scenarios
  - Meteorological conditions
- Alternate scenarios need to be investigated
  - May be worst-case scenario


# The End


# Definitions

# Worst-Case Release - EPA

A worst-case release is defined as:

- The release of the largest quantity of a regulated substance from a vessel or process line failure, and
- The release that results in the greatest distance to the endpoint for the regulated toxic or flammable substance.

(Risk Management Program Guidance for Offsite Consequence Analysis. EPA, 1999)

# Worst-Case Release - EPA

- For most gases, the worst-case release scenario assumes that the quantity is released in 10-minutes.
- For liquids, the scenario assumes an instantaneous spill; the release rate to the air is the volatilization rate from a pool 1 cm deep.
- For flammables, the worst-case assumes an instantaneous release and a vapour cloud explosion.

(Risk Management Program Guidance for Offsite Consequence Analysis. EPA, 1999)

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# MIACC/CSChE Release Event

"…it was decided that the catastrophic, possible maximum or worst-case release would not be considered, since the frequency tends to be very low and valid frequency data are not available. MIACC uses the maximum probable release for risk calculations to provide reasonable estimates."

Generally, MIACC assesses two release events: releases of 10% and 100% of inventory in 30 minutes.

(Risk Assessment guidelines for Municipalities and Industries. MIACC, 1997; Risk Assessment – Recommended Practices for Municipalities and Industry. CSChE, 2004)

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