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SEVESO: HAZID - Major Accident Scenarios and Consequence Analysis

Ike van der Putte

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Seveso Directive – Scope & main obligations

Excluded Sector? (Article 4)

nuclear, transport, military

Yes → Seveso does not apply

No → What is the quantity of dangerous substances? (Annex I)

Lower than lower tier → Seveso does not apply

Quantity above the lower threshold

- Notification
- Major Accident Prevention Policy (MAPP)
- Domino Effects
- Land-use planning
- Inspection

Quantity above the higher threshold

<u>Additionally:</u>

- Safety report (including MAPP and Safety Management System)
- Emergency plans (internal and external)
- Information to the public

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Mandatory SEVESO documents/actions (Summary)*	**Upper tier**	**Lower tier**
Notification to Competent Authorities	Yes	Yes
Major Accident Prevention Policy (MAPP) & Safety Management System (SMS) to implement it	Yes	Yes
Hazard Identification and Risk Assessment (HAZID)	Yes	Yes
Information to Planning Authorities	Yes	Yes
Consider inter-site domino effects	Yes	Yes
Internal Emergency Plan	Yes	`
Information to Authorities for External Emergency Plan	Yes	`
Safety Report	Yes	`
Information to the Public	Yes	Yes

* Ref. Costa Stanisav

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SEVESO inspections Member States obligation (art. 20of Seveso III directive)

- MS shall ensure that the competent authorities organize a system of inspections for SEVESO sites.
- MS shall encourage the competent authorities to provide mechanisms and tools for exchanging experience and consolidating knowledge, and to participate in such mechanisms at Union level where appropriate.
- MS shall ensure that operators provide the competent authorities with all necessary assistance to enable those authorities to carry out any inspection and to gather any information necessary for the performance of their duties for the purposes of this Directive, in particular:
  - to allow the authorities to fully assess the possibility of a major accident and
  - to determine the scope of possible increased probability or aggravation of major accidents,
  - to prepare an external emergency plan and
  - to take into account substances which, due to their physical form, particular conditions or location, may require additional consideration.

The main objectives of inspections/control measures

Inspectors have to verify that: (**art 20)**

- (a) the operator can demonstrate that he has taken appropriate measures, in connection with the various activities of the establishment, to prevent major accidents;
- (b) the operator can demonstrate that he has provided appropriate means for limiting the consequences of major accidents, on-site and off-site;
- (c) the data and information contained in the **safety report**, or any other report submitted, adequately reflects the conditions in the establishment;
- (d) information has been supplied to the public

In Summary

Contents of Upper Tier
SAFETY REPORTS

Minimum SEVESO requirements for a SR (Upper Tier)

1 Safety Management System of the company as implemented in the establishment incl. MAPP
2 Description of establishment and neighboring environment
3 Dangerous Substances (Quantities vs SEVESO Qualifying quantities)
4 Hazard Analysis (HA) : safety critical equipment/circuits
5 Major Accident Scenarios (Reference Scenarios), Phenomena with consequences outside the establishment Worst Case Scenarios (WCSs)
6 Consequence Zones (Z1, Z2, Z3)
7 Risk Assessment RA (Consequence based or QRA)
8 Domino
9 Measures of Prevention, Control and Intervention (limitation of consequences, internal emergency plan)

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Identification and Accidental Risks Analysis and Prevention Methods

A. detailed description of the possible major-accident scenarios and their probability or the conditions under which they occur, including a summary of the events that may play a role in triggering each of these scenarios, the causes being internal or external to the installation;

B. assessment of the extent and severity of the consequences of identified major accidents, including maps, images or, as appropriate, equivalent descriptions, showing areas that are liable to be affected by those accidents;

C. description of technical parameters and equipment used for the safety of installations.

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Risk assessment

Risk analysis is teamwork

Ideally risk analysis should be done by bringing together experts with different backgrounds:

- chemicals
- human error
- process equipment

Risk assessment is a continuous process!

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Risk Assessment

- System definition ↓
- Hazard identification ↓
- Analysis of accident scenarios ↓
- **Estimation of accident frequencies** ↓
- **Consequence analysis and modelling** ↓
- Risk estimation

- Scheme for qualitative and quantitative assessments
- At all steps, risk reducing measures need to be considered

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Risk Analysis – Main Steps

Risk Analysis

- Hazard Identification ↓
- Hazard & Scenario Analysis → Likelihood / Consequences
- Likelihood, Consequences → Risk

- "What if"
- Checklists
- HAZOP
- Task analysis
- Index (Dow, Mond)

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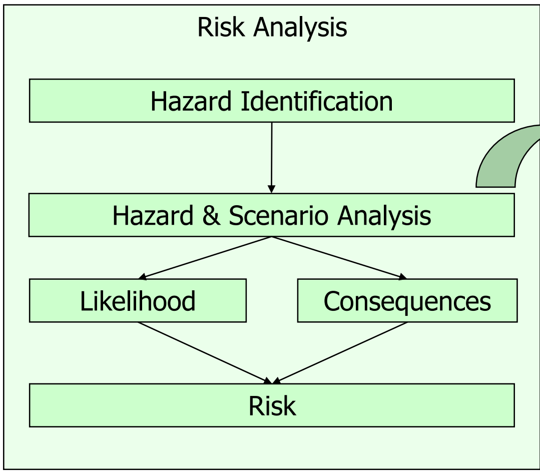
Risk Analysis – Main Steps



- Fault tree analysis
- Event tree analysis
- Bowties
- Barrier diagrams
- Reliability data
- Human reliability
- Consequence models

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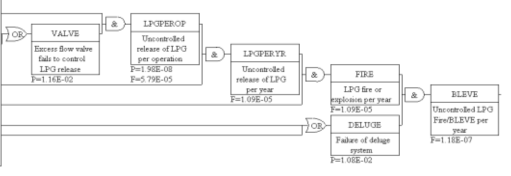
EVENT NAME	DATA REF	DESCRIPTION	FAILURE RATE	Trep/ Ttest	PROB	R/U
HOSEFAIL	CCPS	Failure of hose during unloading	4.99E-03	3.42E-04	1.71E-06	R
OPSFAIL1	Estimate	Operator fails to activate excess flow valve			1.00E-02	-
VLVFAIL	CCPS	Excess flow valve fails to shut when activated			1.61E-03	-
RAILCARS	Butan	Number of railcar unloading operations per year	5.50E+02			-
IGNITION	Estimate	Ignition Source			1.00E+00	-
OPSFAIL2	Estimate	Operator fails to activate deluge system			1.00E-02	-
H20-FAIL	CCPS	Deluge systems fails to operate when activated	8.46E-02	1.92E-02	8.12E-04	U



Logan Fault and Event Tree Analysis Version 5.30
Date (dd-mm-yy) :01-11-01 Time: 11.37.45
Fault Tree File :S:\Projects\360006-01\23 Health & Safety\016 Risk Assessment\Fault Trees\LPG Release 1
Cutset Order :6
Proof Tests :Simultaneous

FIGURE 1. FAULT TREE FOR UNCONTROLLED LPG FIRE/BLEVE PER YEAR

Based on historical data and Guidelines for Process Equipment Reliability Data, Centre for Chemical Process Safety (CCPS) of the AIChE, 1989.
Ref. RPS/BKH/PM report REAP 2002

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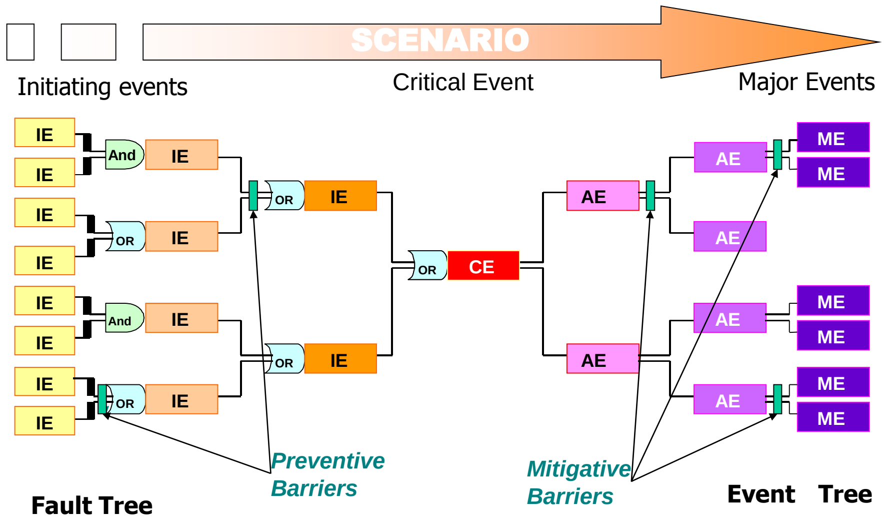
Bow-tie



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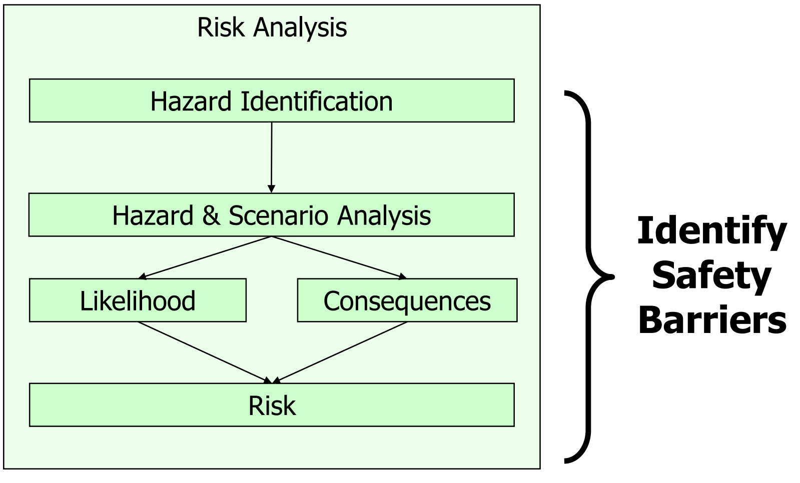
Risk Analysis – Main Steps



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The main elements in any risk analysis process are as follows:

- hazard identification;
- accident scenario selection;
- scenarios' likelihood assessment;
- scenarios' consequence assessment;
- risk ranking;
- reliability and availability of safety systems

With regard to the hazard identification, a range of tools exists for systematic assessments, which are selected depending on the complexity of the individual case.

The identification of hazards is followed by designation of ***reference accident scenarios*** which form the basis for determining whether the safety measures in place or foreseen are appropriate.

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A. Description of major-accident scenarios, initiating causes and the conditions under which they occur

A structured approach to scenario selection is a crucial step in the overall analysis. The safety report should, therefore, outline the principles and procedures followed (SMS) to determine the scenarios. In doing so, events which are documented in accident databases, near-miss recording, safety alerts and similar literature must be reviewed when drawing up the list of scenarios and appropriate lessons learnt incorporated.

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A major-accident scenario for the purposes of the safety report usually describes the form of the loss of containment specified by its technical type e.g.:

- vessel rupture
- pipe rupture
- vessel leak, etc.

and the triggered event, namely:

- fire
- explosion
- release of hazardous substance(s)

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The following non-exhaustive list provides the most relevant event types that describe the consequences of the top event development (outcome):

- pool fire
- flash fire
- tank fire
- jet fire
- VCE (vapour cloud explosion)
- toxic cloud
- BLEVE (boiling liquid expanding vapour explosion)
- soil/air/water pollution

A point to note is that these events may occur in

- process units
- storage units
- pipe work
- loading/unloading facilities
- on-site transport of hazardous substances.

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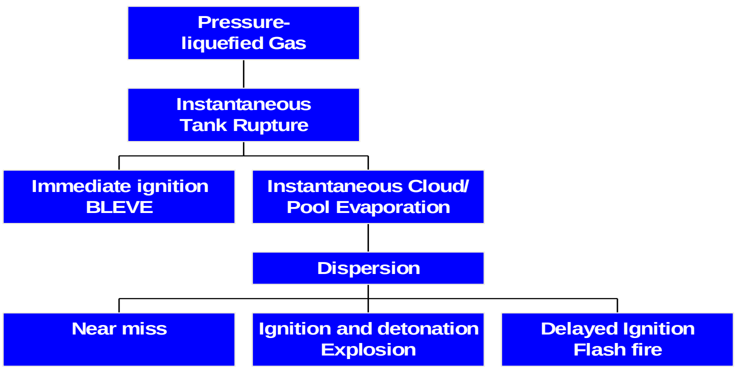
Consequence event tree for a flammable pressure-liquefied gas – instantaneous rupture

Chart Title



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Example BLEVE

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The safety report must demonstrate
that, of these possible scenario elements, the relevant scenarios were chosen.

The selection may follow strategies such as:
- event likelihood
- consequences
- how comprehensive or representative the scenario is.

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It is necessary to consider the causes of the potential accident; the most relevant of these are:

Operational causes (malfunctions, technical failures, ignition, kock-on effects etc)

Internal causes may be related to fires, explosions or releases of dangerous substances at installations within the establishment affecting other installations leading to a disruption of normal operation (e.g. the fracture of a water pipe leading to a disruption in the cooling capacity on site).

External causes *(fire, explosions toxic release of neighboring plants –Domino Effects; Natural hazards-NATECH; transportation and transport off site etc.*

Plant security *(intentional acts)*

Other accident causes (related to design, construction and safety Management)

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Consequence Analysis - modelling

Results of modelling exercises are expressed in terms of severity of (potential) impact. For safety reports, potential impact is commonly defined in terms of human health, although relative property or environmental damage may also be presented.
Two main approaches are used to measure severity of impact:

• the **damage probit curve** (impact related to a probability that certain damage (physiological or material) will occur)

• **fixed damage thresholds**. (links specific impacts, such as the onset of death or serious injury, to specific level and time of exposure). Threshold levels for accidental airborne releases of toxic substances, static or dynamic thermal radiation, and overpressure have been calculated by various expert groups

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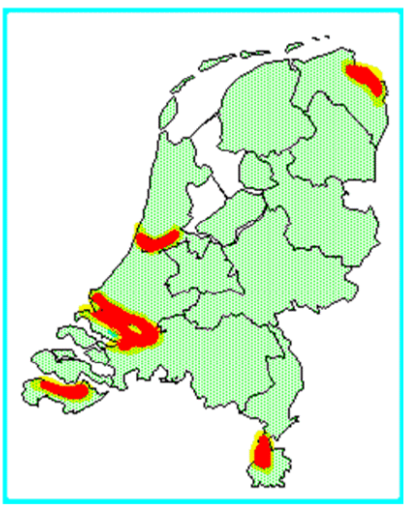
External Safety in the Netherlands



Over 5000 establishments
have hazardous substances:

- **2200 LPG tankfilling st**
- **1000 Chemicals storages**
- **500 NH_3 cooling units**
- **300 Seveso sites**
- **30 Marshalling yards**
- **… Other sites**

+ Transport (rail, water,road)

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Harmonised model Netherlands SAFETI

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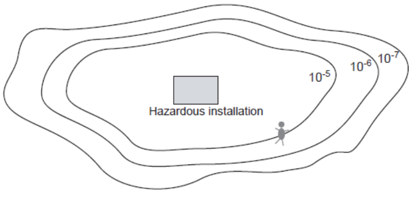
Dutch study revealed that different QRA software packages often give very different results. Safeti has been selected as the QRA model for the Netherlands

The risk tool SAFETI calculates the individual risk (risk at specific location) and societal risk (risk to overall population) of accidental releases of toxic or flammable chemicals to the atmosphere. This calculation includes consequence modelling (discharge and atmospheric dispersion, toxic effects, flammable effects) and subsequent risk modelling.

The individual risk index (IR) is the probability that an average unprotected person, permanently present at a certain location, is killed in a period of one year due to an accident resulting from a hazardous activity. The IR is mainly used for land-use planning.

$$\text{IR}(x,y) = \sum_{i=1}^{m} \lambda_i \cdot \Pr(\text{Fatality at } (x,y) \mid \mathcal{A}_i)$$

where $\mathcal{A}_i$ denotes accident of type i, and λ_i is the frequency of $\mathcal{A}_i$



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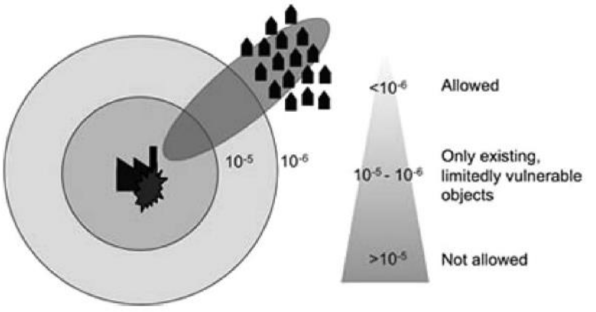

Individual risk contours around a hazardous establishment and the area affected by an individual accident scenario.
(ref Jongejan et al 2010)

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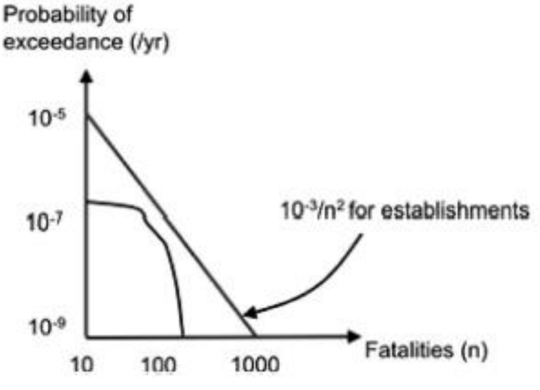

The Dutch societal risk criterion for hazardous establishments and a fictitious FN-curve.

The Dutch societal risk criterion of 10−3/n2 per installation per year was initially developed for LPG-fuelling stations. It was later applied to all Seveso establishments.

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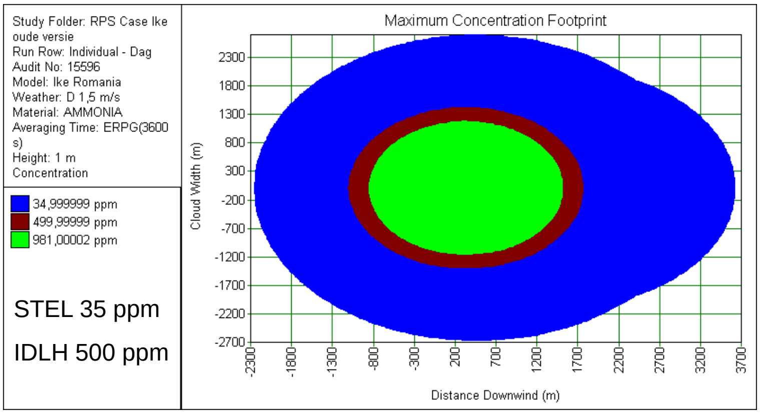
Harmonised model Netherlands SAFETI



STEL = Short term exposure limit
IDLH = Immediate Dangerous to Life and Health

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Harmonised model Netherlands SAFETI

Source:QRA's FOR DUTCH INSTALLATIONS
IChemE SYMPOSIUM SERIES NO. 153 2007

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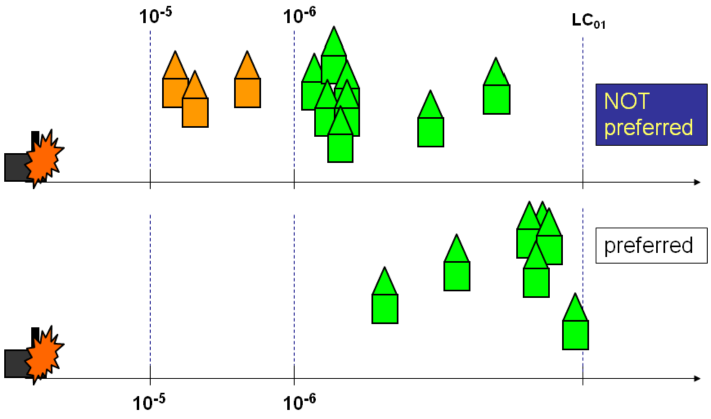
Spatial Planning : new situations



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Two types of estblishments

establishment categories: <u>safety distances</u>

LPG tankfilling stations,
Chemicals storages,
Ammonia cooling installations

<u>risk assessment</u> and evaluation by <u>risk criteria</u>
for: **300 Seveso companies,**

+ Railroad marshalling yards,
+ ...

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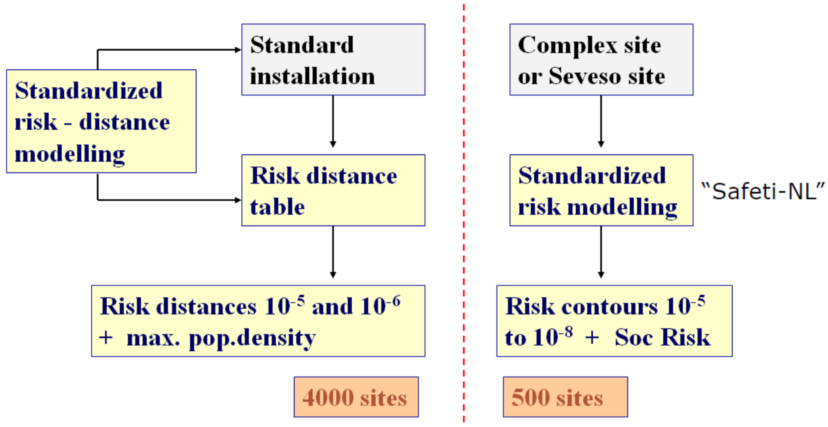
Fixed safety distances vs QRA



Ref. Robert Plarina Netherlands Ministry of Environment

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Scenario	Applicable to type of facility	Effect studied	Criteria corresponding to first deaths	Criteria corresponding to first irreversible effects
BLEVE	Liquefied flammable gases	Thermal Radiation	5 KW/m2	3 kW/m2
UVCE	Liquefied flammable gases	Overpressure	140 mbar	50 mbar
Total instantaneous LOC	Vessels with toxic gases (liquefied or not)	Toxic Dose	Based on LC1 and exposure time	Based on IDLH and exposure time
Catastrophic rupture of the largest pipeline Q highest mass out low	Toxic gas installations (containment designed to resist external damage or internal reaction)	Toxic Dose	Based on LC1 and exposure time	Based on IDLH and exposure time
Fire in the largest tank **Explosion of the gas phase in fixed roof tanks** **Fireball and projection of burning product due to boilover**	Large vessels containing flammable liquids	Thermal Radiation Overpressure Missile projection	5 KW/m2 140 mbar	3 kW/m2 50 mbar
Explosion of the largest mass of explosive present or explosion due to a reaction	Storage or use of explosives	Thermal Radiation Overpressure Missile projection	5 KW/m2 140 mbar	3 kW/m2 50 mbar

Ref. G. Papadakis SEVESO SERVIA June 2013

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Example of Consequence Zones Criteria (LPG)

Type of Consequence	DOMINO effects 37.5 KW/m2 700 mbar
Serious and non recoverable damage to the structures and the walls of buildings ZONE I (Internal Zone) Protection Zone of Response Teams	ZONE I 15 KW/m2 350 mbar
Damage to the structures and the external walls ZONE II (Intermediate Zone) Protection of Public – Serious Consequences	ZONE II 6 KW/m2 140 mbar
Damage to the doors and windows, light ruptures in walls ZONE III (External Zone) Protection of Public – Considerable Consequences	ZONE III 3 KW/m2 50 mbar

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Example of Consequence Zones Criteria (Toxic Cloud)

Type of Consequence	DOMINO effects –
ZONE I (Internal Zone) Protection Zone of Response Teams	ZONE I LC50
ZONE II (Intermediate Zone) Protection of Public – Serious Consequences	ZONE II LC1
ZONE III (External Zone) Protection of Public – Considerable Consequences	ZONE III IDLH

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Risk management in Europe

- "*Generic distances*" based on environmental impact in general (noise, smell, dust, etc.).
- *Consequence based ("deterministic" or "Qualitative")*
  Safety distances are based on the extent of consequences (effects) of distinct accident scenarios ("worst case" or "reference" scenarios).
- *Risk based ("probabilistic" or "Quantitative")*
  Quantitative risk analysis (QRA) includes an analysis of all relevant accident scenarios with respect to consequences and likelihood (expected frequency), and results in calculated values of individual risk and societal risk, which can be compared with acceptance criteria.

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References

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CASE LPG STORAGE FACILITY - Slovenia

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