RISK ASSESSMENT AND PREVENTION OF MAJOR ACCIDENTS

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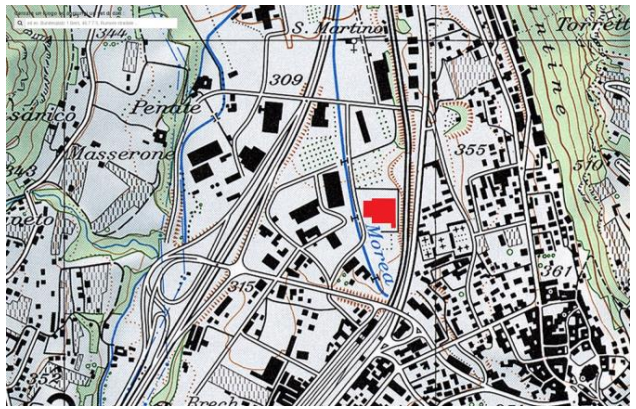
INTRODUCTION

1951 ARGOR S.A. established in Chiasso

1986 Partnership with HERAEUS

1988 ARGOR-HERAEUS' refinery relocated in Mendrisio in a sparsely built area

2023 Along the 35 years elapsed both the production of the factory located in Via Moree and the population density around it increased dramatically.
The risk assessment and the prevention of major accidents have thus become a cornerstone of the sustainability of our presence in the small town of Mendrisio.



1988

65 employees
low density area

present

400 employees
high density area

SOME MAJOR ACCIDENTS IN THE HISTORY YOU PROBABLY REMEMBER

- SEVESO, Italy, 1976
- Dioxin release into the air
- BHOPAL, India, 1984
- Methyl isocyanate release into the air
- SCHWEIZERHALLE, Switzerland, 1986
- Pollution of the Rhine river after a fire at an agrochemicals warehouse
- BEIRUT, Lebanon, 2020
- Ammonium nitrate explosion

DIRECTIVES AND REGULATIONS

Along the years many directives and regulations have been enforced in order to improve safety, to **prevent major accidents** and to **protect the population and the environment** against their consequences, to **allow the emergency services to intervene effectively** and the authorities to **exercise control over dangerous activities**. Among them following ones can be cited:

› FOR TRANSPORTS:
  • ADR (Road) – RID (Rail) – IATA DGR (Air) – ADN (Waterways) – IMDG Code (Maritime)

› FOR STATIONARY INSTALLATIONS:
  • Seveso Directive (EU)
  • Major Accidents Ordinance (Switzerland)

THE SWISS MAJOR ACCIDENTS ORDINANCE (MAO)

The Major Accidents Ordinance (MAO, SR 814.012) is used by the authorities in order to **assess the level of hazard** represented by the companies operating on their competence area and to **keep a register** thereof.

It helps to **coordinate the readiness and the intervention of the emergency services** and provides a standardized database for them; on top of this it constitutes for the managers of dangerous activities a valuable **tool for the improvement of the safety**.

The MAO is applicable to establishments where the **threshold quantities** for substances, preparations or special wastes specified in its Annex 1.1 are exceeded.

Pipelines, railways, major roads and the Rhine (the only navigable Swiss river) are also subject to the MAO, as well as establishments with specific biohazards.

THRESHOLD VALUES

As a general rule, the threshold values are defined by the MAO basing on the Hazard Phrases (H; EUH) defined in the Globally Harmonized System for the Classification and Labelling of Chemicals (GHS).

Threshold values for special waste are listed in the Swiss Ordinance on the Lists for the Movement of Waste (RS 814.610.1, Annex 3).

Some examples of threshold values are given here:

Heating oil	500’000 kg
Gasoline	200’000 kg
HCl 31%	20’000 kg
HNO_3 62%	20’000 kg
CuO sludges (special waste)	20’000 kg
Hydrogen	5‘000 kg
$NaHSO_3$ solution	2’000 kg
Sulphur dioxide	2’000 kg
Hydrazine	500 kg
Chlorine	200 kg

FIRST STEP OF THE MAO ASSESSMENT: THE SUMMARY REPORT

The companies resulting subject to the MAO must submit to the enforcement authorities a **Summary Report** including:

- A concise **description of the establishment**, together with a **general plan** and **information on the surrounding area**;
- A list of the **maximum quantities of the substances**, preparations or special wastes present in the establishment which exceed the threshold quantities
- Summary informations on the **processes** occurring in the establishment and the details of the **existing safety measures**.
- An estimate of the extent of **possible harm to the public** or **damage to the environment** resulting from major accidents

SECOND STEP OF THE MAO ASSESSMENT: THE RISK ASSESSMENT

If serious harm to the public or damage to the environment in case of major accidents cannot be excluded, the enforcement authority requests a **Risk Report** in accordance with the MAO.

If the assessed risk is **unacceptable**, the enforcement authority shall order **additional safety measures**; if necessary, **restrictions or prohibitions** may be imposed.

When the circumstances change significantly, as in the case of

- use or storage of new hazardous materials
- introduction of new processes
- significant increase in production volumes
- significant changes in the potentially endangered area

the report must be updated and resubmitted.

our experience:

- Carry out the risk assessment considering the local area plan rather than the current situation

RISK QUANTIFICATION

The Risk Report requires an in-depth assessment of the residual risk based on **selected scenarios** chosen on the base of the results of the Summary Report.

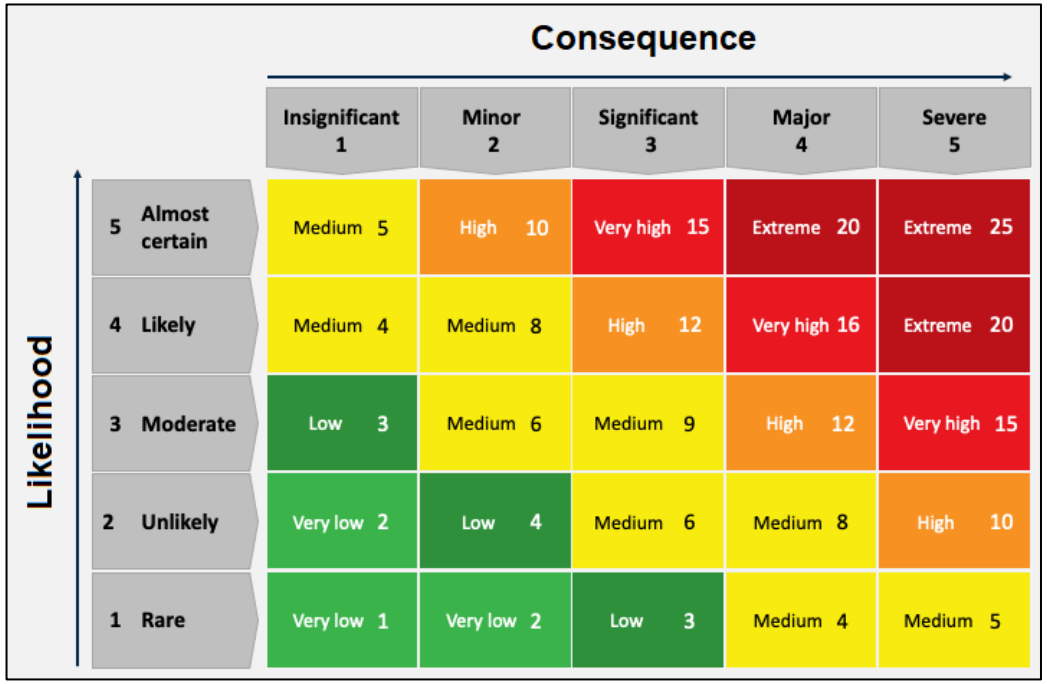
Similarly to a simplified risk assessment based on a risk matrix depicting the severity of the expected damage caused by an accident against its likelihood, the MAO risk assessment makes use of a **risk diagram** where the cumulated risk of the examined events is represented against the potential damage.

The **likelihood** is given in occurrences per year, whereas the **severity of the damage** is represented by a **logarithmic index** defined in the enforcement aids of the Ordinance and indicating:

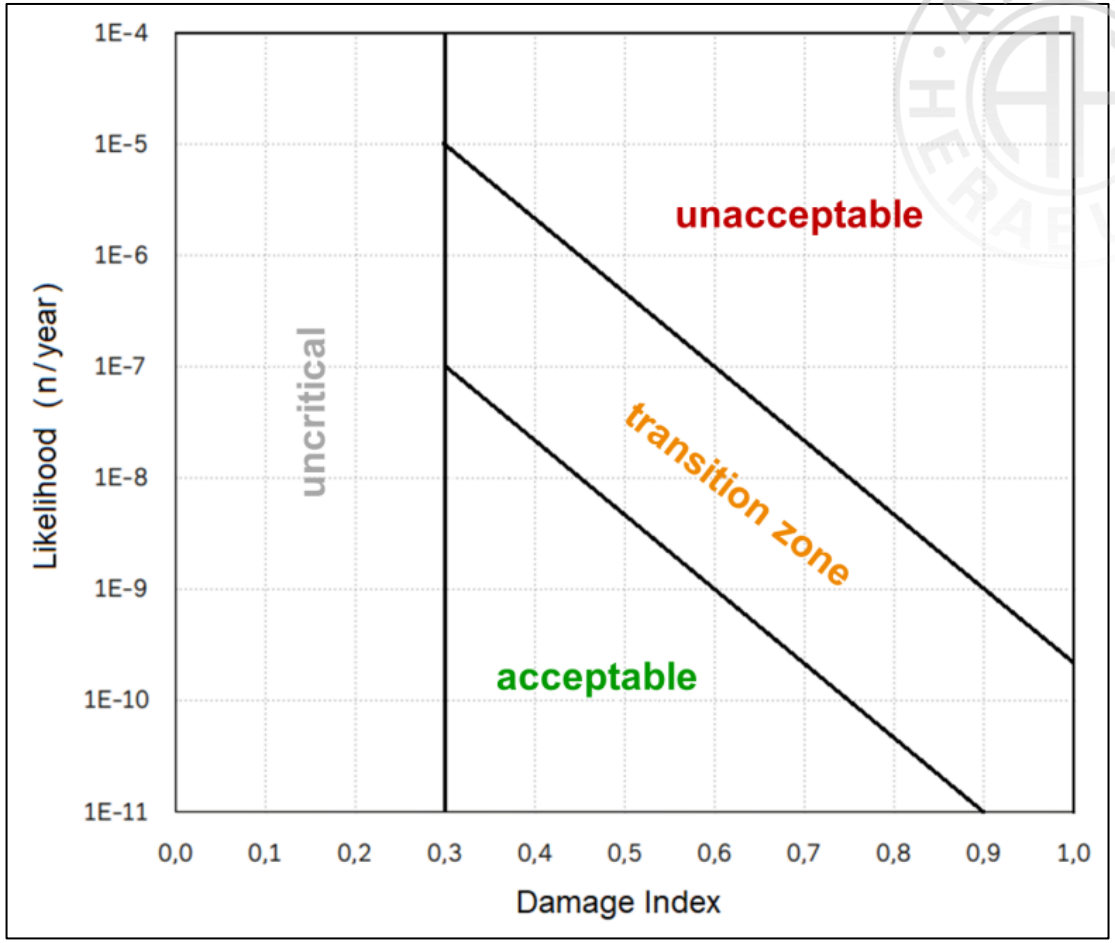
- Casualties
- Injured people (specifically for biohazard)
- Polluted surface waters (in km^2 or m^3)
- Polluted groundwater (shortage in people and months)
- Deteriorated soil fertility (in km^2 and years)

This allows to represent and to assess all different risks in a **unified manner**.

RISK QUANTIFICATION



Risk Matrix



MAO Risk Diagram. For most indicators a 0.3 units index increase reflects a 10-fold increase of the damage extent

FAULT TREE

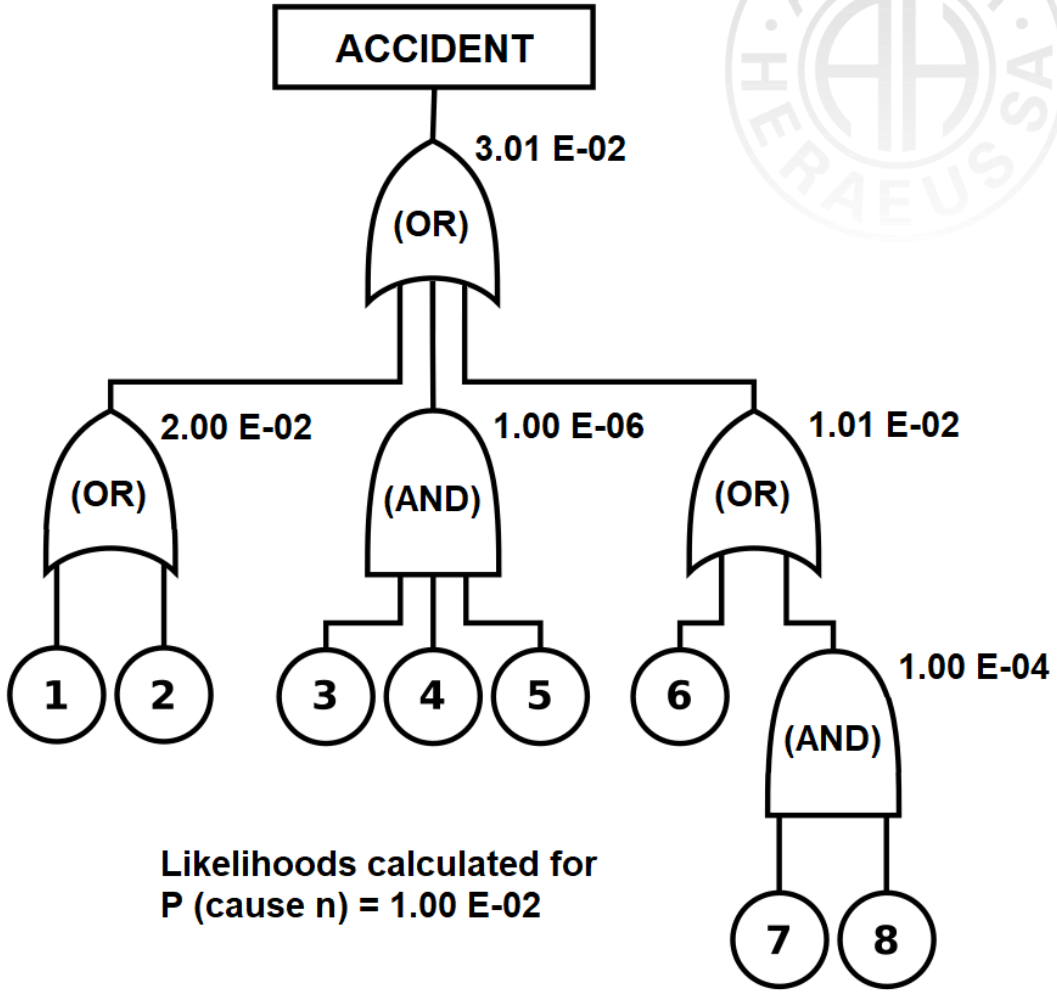
To calculate the risk that a major accident happens, develop a **fault tree** including all conditions that can lead to its occurrence.

Note: the fault tree will help you to find the best way to reduce the likelihood of the accidents selected for your scenarios!

Failure rates can be found in technical literature.

The **combined probability** of two concurring causes is:

- the **product** of their ones if both must occur (**AND**)
- the **sum** of their ones if any of them must occur (**OR**)



FAULT TREE

our experience:

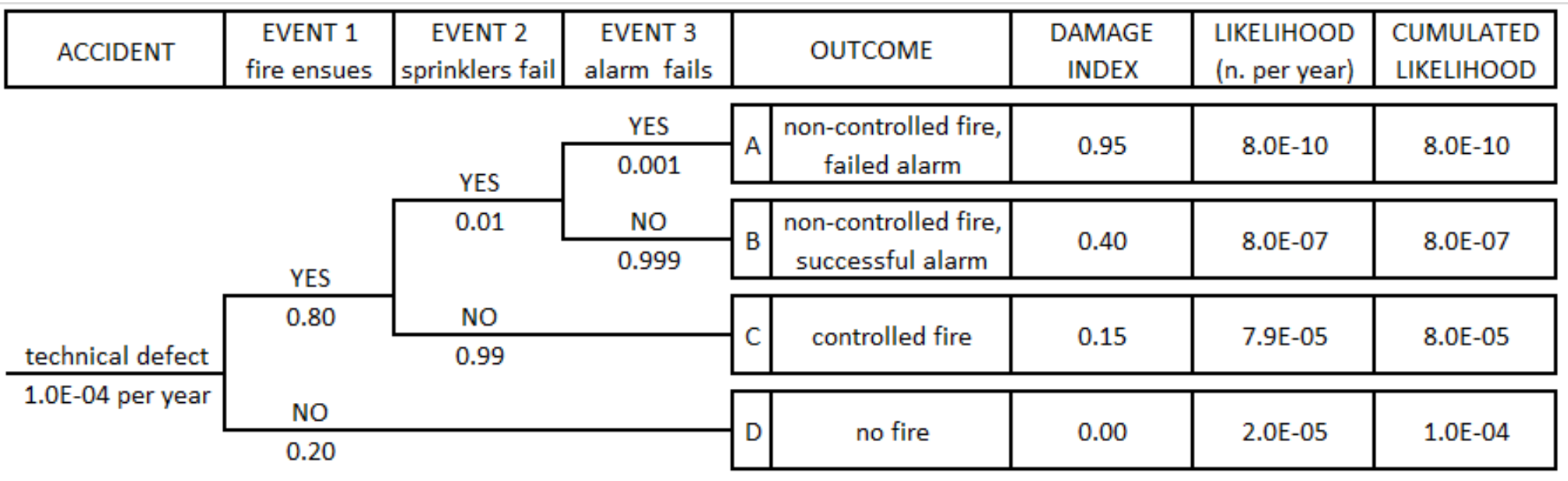
To improve safety, introduce **redundancy** (“AND”) where appropriate

Where alternative paths (“OR”) exist, focus your improvement efforts **onto the more critical factor**

Human failure rate is much higher than the one of technical safety measures (indicatively by two orders od magnitude).
Therefore, if you have a step where your safety may be independently affected either by human failure OR by a technical failure your technical safety may be critically wasted by the human element!

EVENT TREE

To calculate the potential damage from an accident, describe in an **event tree** all conceivable ways it can unfold (**sub-scenarios**) as in following example:

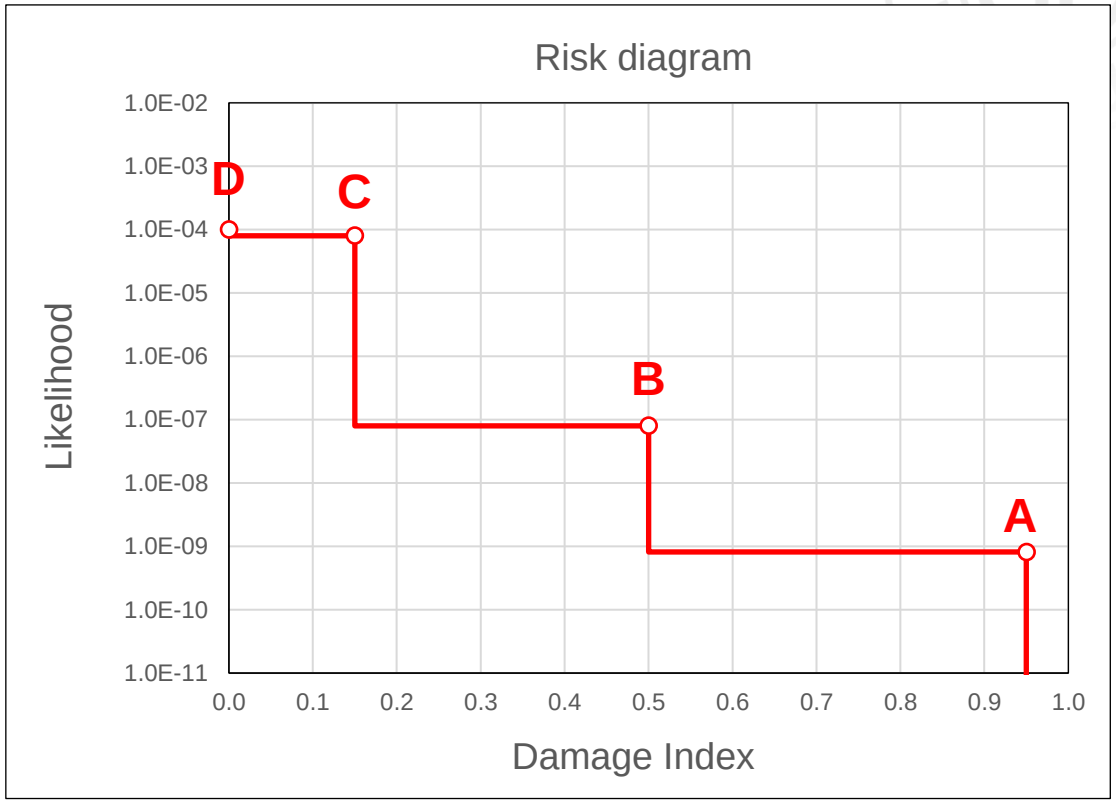


ACCIDENT	EVENT 1 fire ensues	EVENT 2 sprinklers fail	EVENT 3 alarm fails	OUTCOME		DAMAGE INDEX	LIKELIHOOD (n. per year)	CUMULATED LIKELIHOOD
				A	non-controlled fire, failed alarm	0.95	8.0E-10	8.0E-10
				B	non-controlled fire, successful alarm	0.40	8.0E-07	8.0E-07
				C	controlled fire	0.15	7.9E-05	8.0E-05
				D	no fire	0.00	2.0E-05	1.0E-04

For **each outcome** calculate the **probability** by multiplying the likelihood of the accident by the probabilities of all elements of the event chain, and the **damage** according to an appropriate model specific to the considered type of scenario

RISK CURVE

- Calculate the **cumulated likelihood** starting with the point with the highest damage index and finishing with the point with the lowest one.
- Plot the resulting **risk curve** in the standardized Risk Diagram
- If your risk assessment include different scenarios, add up all individual risk curves



RISK CALCULATION

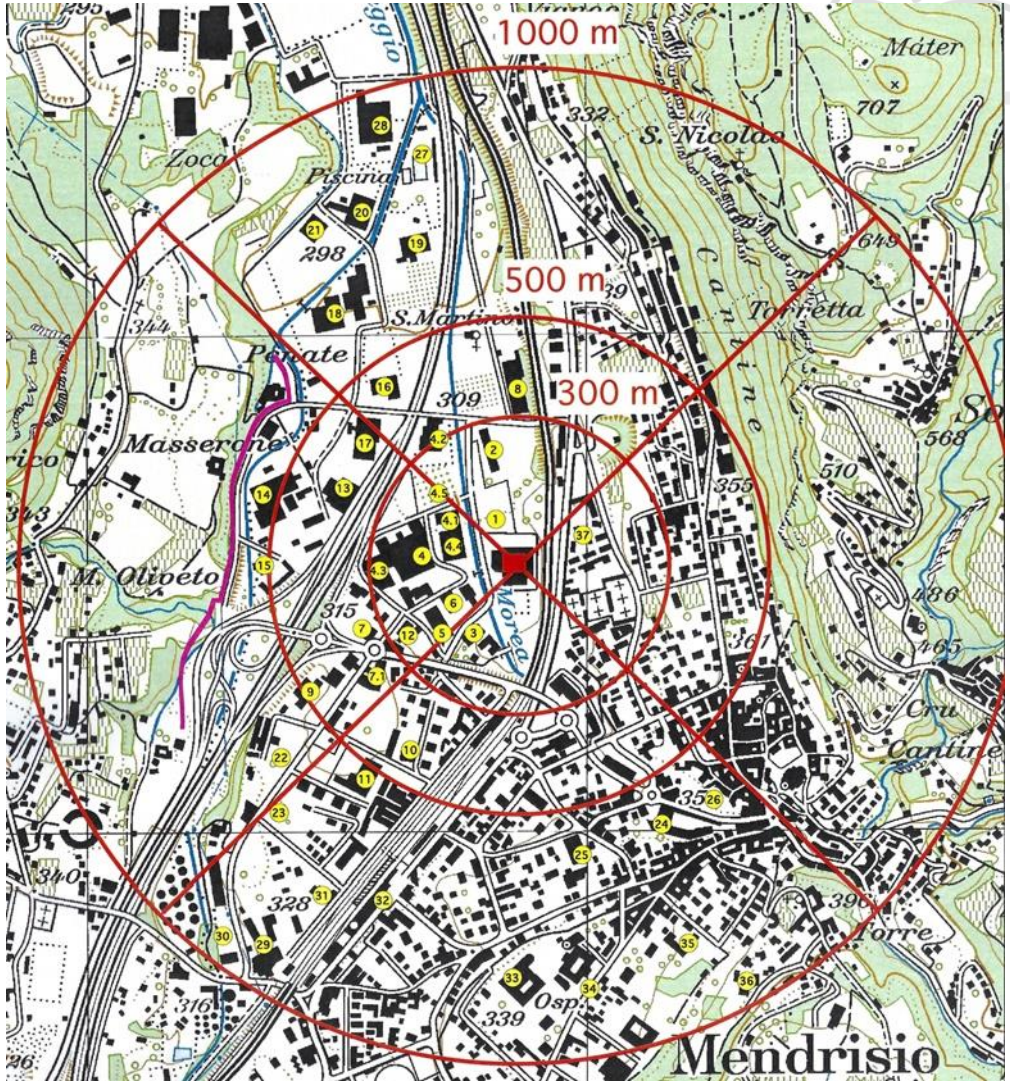
Critical scenarios typically involve the **release of toxic gas in the atmosphere**.

The spread of the toxic cloud can be calculated with a **dedicated software** considering

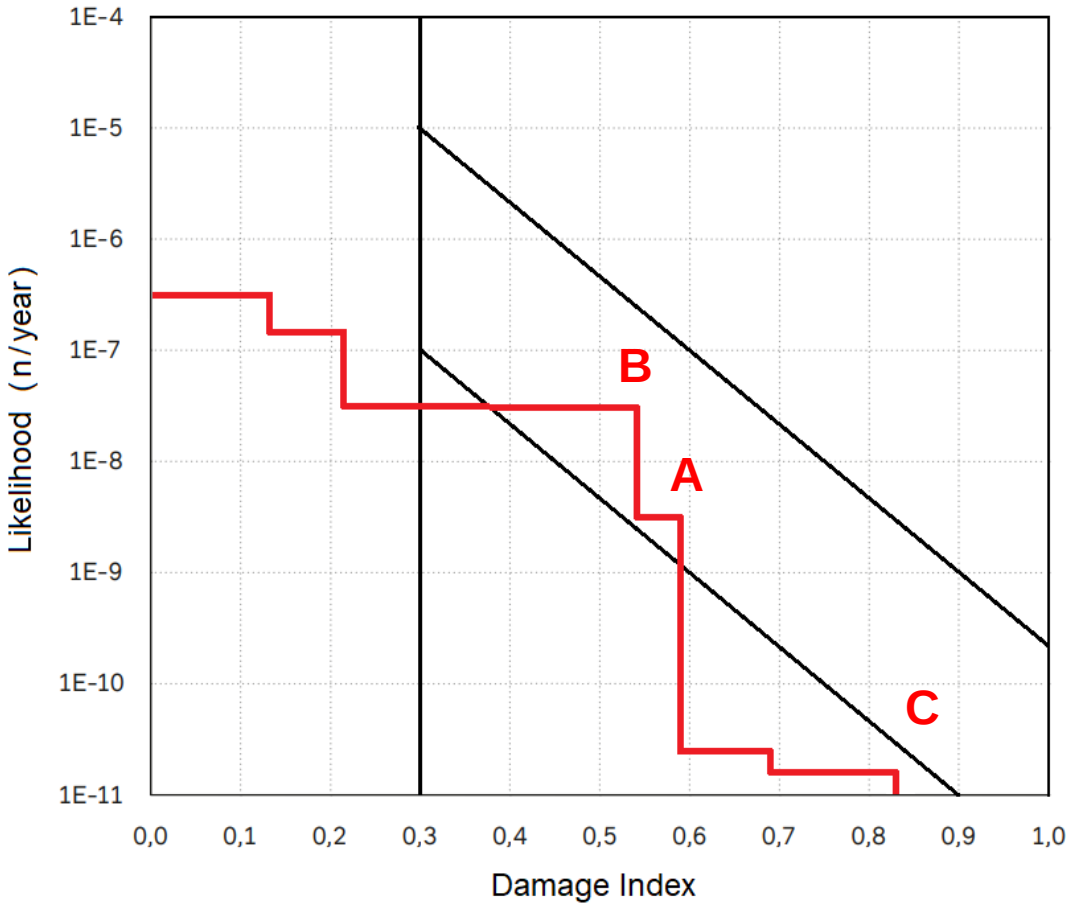
- The local topographical data (geodata)
- The emission rate and duration and the elevation of the emission source
- The wind velocity and direction

The resulting damage can then be calculated considering

- The population density in the affected area, differentiated for time & day
- The toxicological data for the released gas



RISK ASSESSMENT



Once the risk curve has been plotted, situations requiring corrective action become evident.

Point A might be tolerable; a weighing of costs vs. benefits should be discussed with the enforcement authority

Point B requires action in order to be brought into the acceptability area

Point C is formally acceptable. Since the corresponding damage is quite high, considerations on further safety improvements would be however advisable

RISK MITIGATION

Our experience:

A risk mitigation can be achieved

- **reducing the likelihood of an accident occurring** through improved safety measures along the fault tree, e.g. with redundant checks, up-to-date technical solutions, appropriate maintenance. Change of process technology and replacement of hazardous chemical reagents may be decisive but are not always possible.
- **reducing the likelihood of the worst sub-scenarios unfolding** once the accident has happened (event tree), e.g. with interlocks allowing immediate reaction, appropriate intervention drills and co-ordination with external emergency services, passive safety measures like retention basins for polluted water.
- **reducing the severity of the damage**, e.g. limiting the stored or used quantities of hazardous products. Since the concept of risk assessment is related to orders of magnitude, only marginal benefits can be expected from this option

RISK MITIGATION

A selection of our achievements:

Replacement of human safety elements by technical measures wherever possible

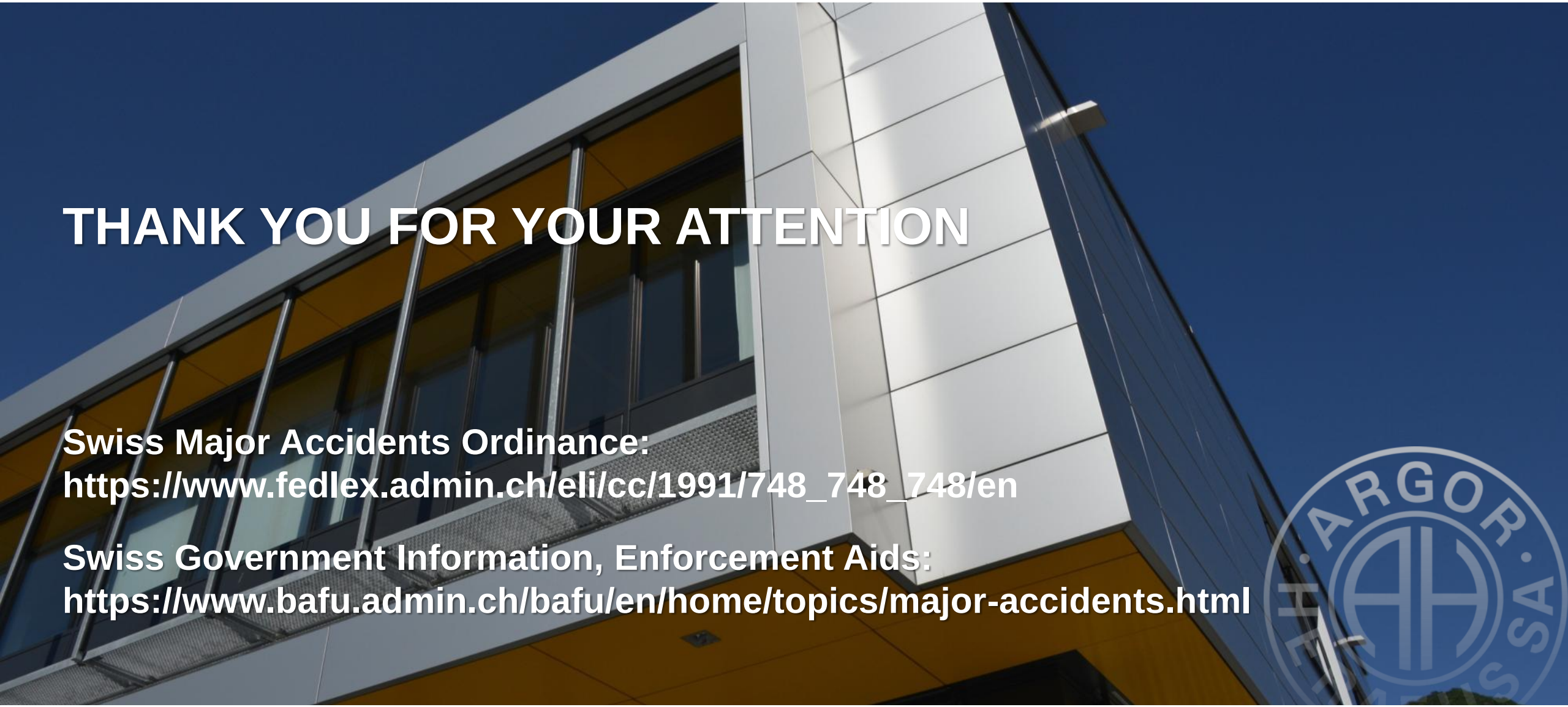
Introduction of redundant organizational and technical safety measures where critical (e.g. four-eyes checks)

Replacement of liquefied Cl_2 and SO_2 for chemical processes by NaOCl and $NaHSO_3$

Automated interruption of HNO_3 dosing for dissolution reactions when anomalous NOx levels are measured at the main stack

Interlock of the inlet valve of the 25-m^3 HCl, HNO_3, $NaHSO_3$ storage tanks with conductivity measurement of the inflowing liquid and with anomalous NOx detection at the stack

Basement beneath the chemical production areas conceived as extinguishing water containment



THANK YOU FOR YOUR ATTENTION

Swiss Major Accidents Ordinance:
https://www.fedlex.admin.ch/eli/cc/1991/748_748_748/en

Swiss Government Information, Enforcement Aids:
https://www.bafu.admin.ch/bafu/en/home/topics/major-accidents.html