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Optimization of sensor locations using dispersion modelling for application to industrial Facilities

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Context and origin of this work

Gaseous leakage detection is a major issue for numerous industrial facilities for both flammable and toxic leaks

Several challenges

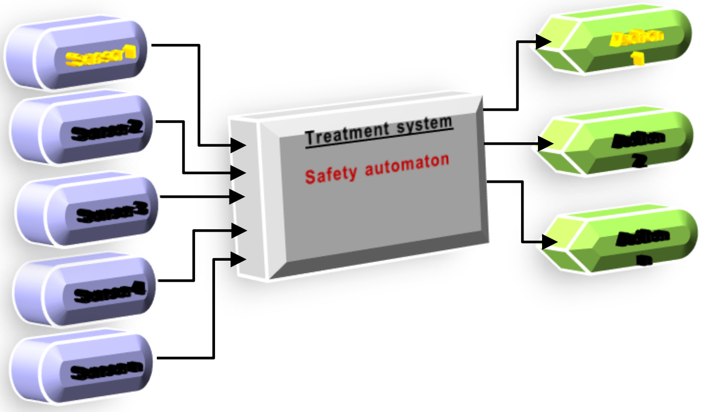
- Detection delay
- Optimization of the sensor number
- Selection of an activation strategy (1/2 – 2/3 - …)

Observation of the existing situation

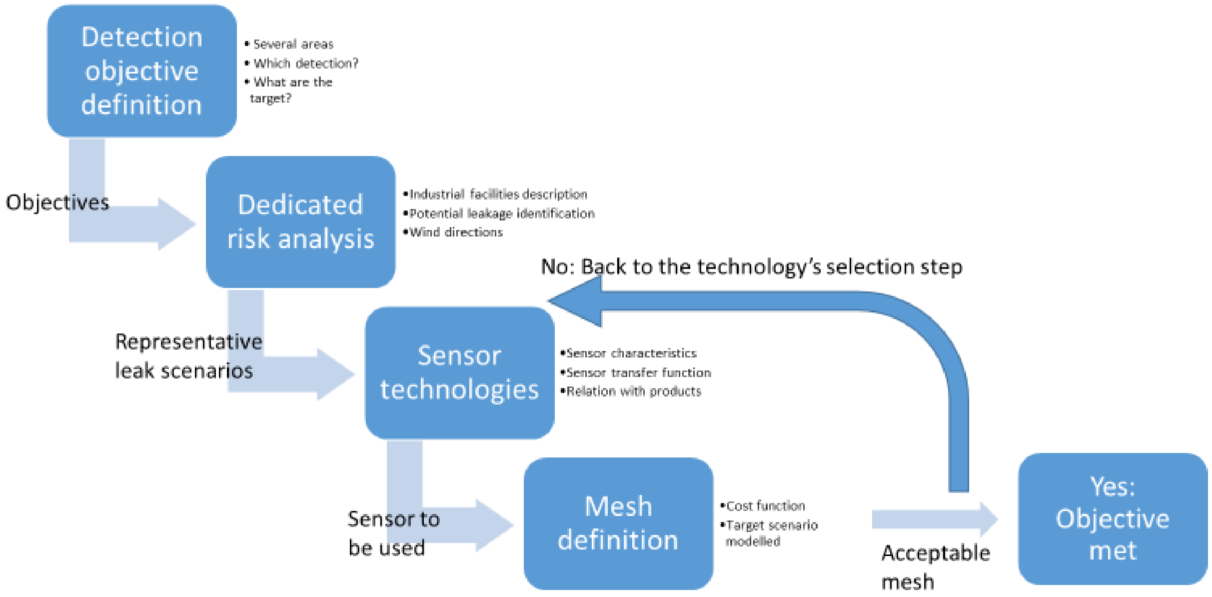
- Sensor are located in surrounding of risky areas
- Without a specific risk analysis, based on the risk study's one
- Current development of some standards (*IEC 62990-2*) but difficult to apply on real situations

Our objectives

- Defining design rules for sensor network that includes all (or almost all) parameters
- Provide a control strategy for the administration



Sensor mesh definition process



Definition of the objectives

Leak detection is leak dependant

- Workers safety implies very small leak detection
- Land use planning implies focussing on major leaks
- Protection of the industrial installations (domino effect)

For an identical installation, the sensor mesh will be objective dependant

Those preliminary questions are crucial for the risk analysis

Dedicated risk analysis

Why a dedicated risk analysis

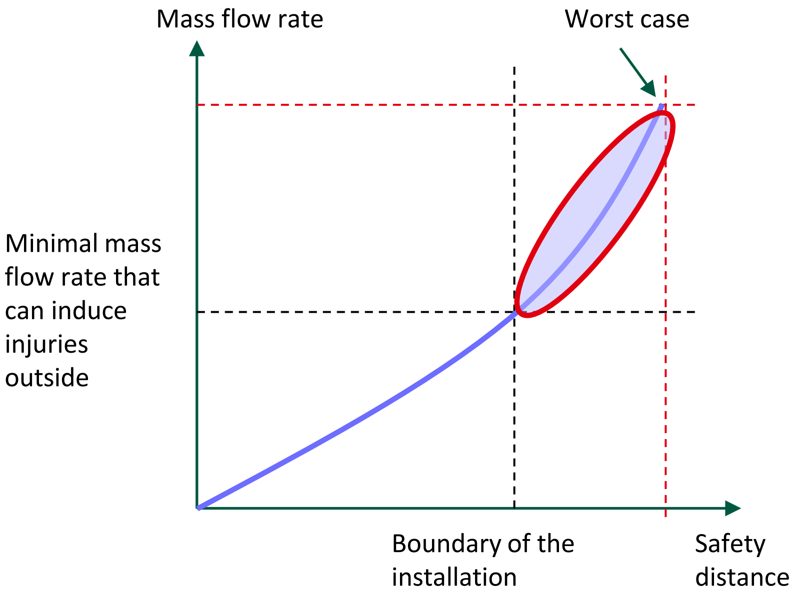
- Risk analysis is commonly done for major scenarios: what is the worst case
  ex : full line rupture

For sensor mesh design, all scenarios that can induced the considered consequences should be modelled

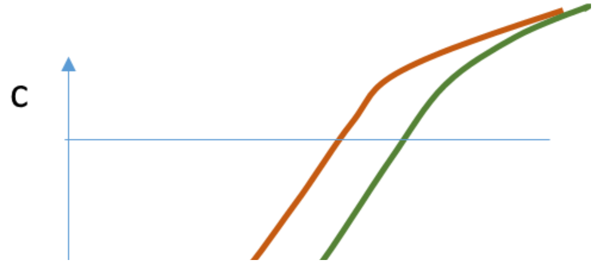
- Not only full line rupture but also the leak section that correspond to the minimum flow rate that induced the expected consequence (death, injuries, …)

Same analysis for

- Leak direction
- Wind direction
- Product, if chlorine is the worst, maybe other gases (and other installations) should be considered

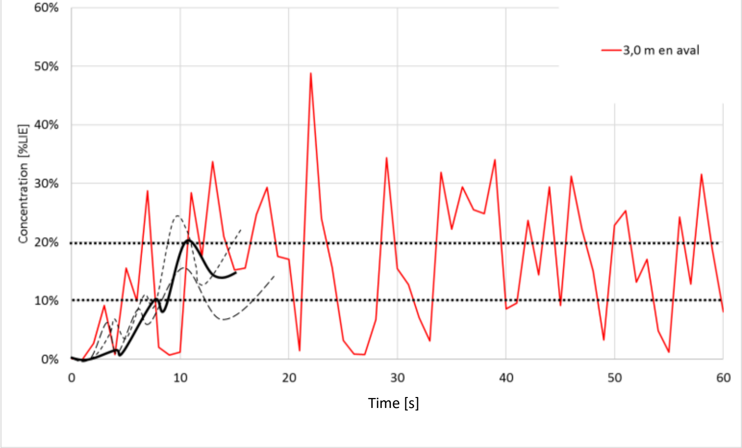


Sensor selection



Several parameters should be considered

- Expected response time of the safety system: Sensor is not an instantaneous system, neither closure valves
    - Time to threshold limit may vary from a technology to another
    - Time to alarm might be dozens of seconds



- Detection threshold
    - Lower than expected value where the sensor is

- Sensor technology: measuring range, detection area (fixed punctual sensor, linear IR,
    - Importance of the unsteady effect

- Reliability and availability

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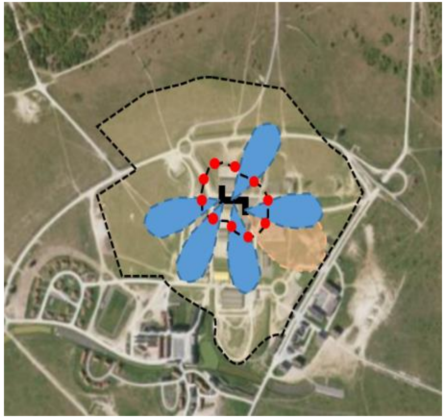
Sensor mesh definition

Dispersion modelling should be used

Several steps to be considered

- Model first the lowest mass flow rate → expected concentration are the lowest
- Leak direction should be the one with the shortest plume length, for a given threshold
- Consider the detection threshold based on the concentration distribution
- Propose a first sensor distribution based on an homogeneous cloud hypothesis
- Validation of the sensor mesh using numerical modelling (including CFD when relevant)



An example of application

Consideration of a fictitious configuration

- Industrial facility with ammonia (in red)
- Several buildings in the surrounding : the closest is located at 270m of the potential releases
- Several installations to be considered
  - Transportation pipes
  - Storage
  - Unloading area

Definition of the sensor mesh objective

➔ **Preventing lethal effect on the inhabited area**

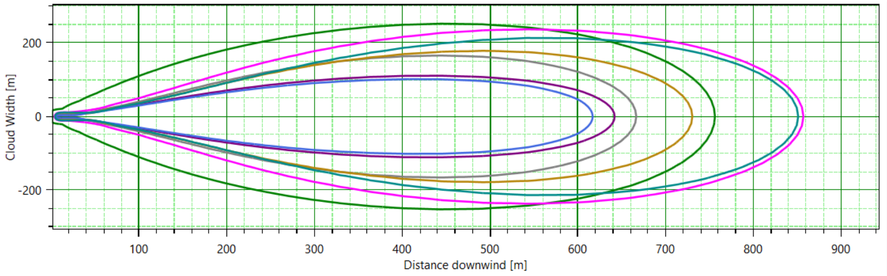
Risk analysis

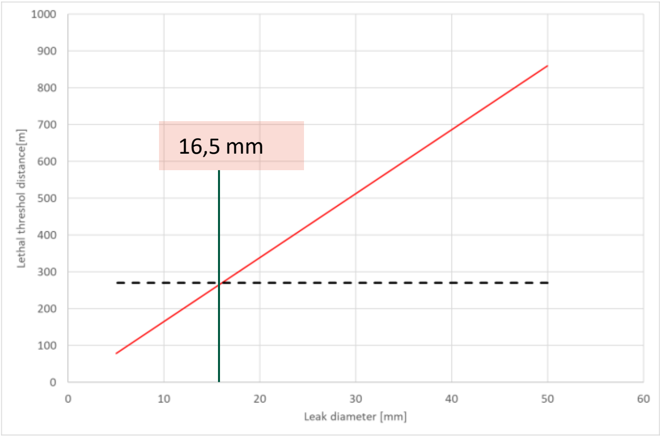
Modelling is a part of the risk analysis

- Worst case of the land use planning study: 50 mm in-diameter release of liquified ammonia
- Horizontal jet
- Computed distance
  - 3500 m for the non-reversible threshold
  - 800 m for the lethal threshold (3F and 3D)

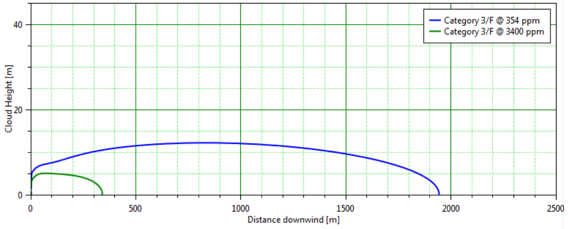
The minimum diameter than induce lethal effect outside the installation is 15 mm

Zoom on the lethal zone

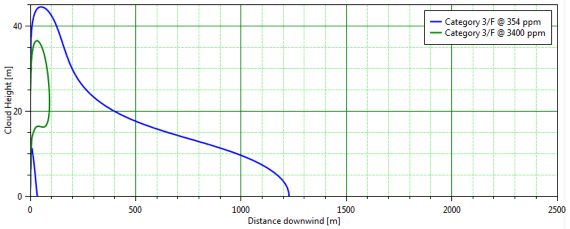




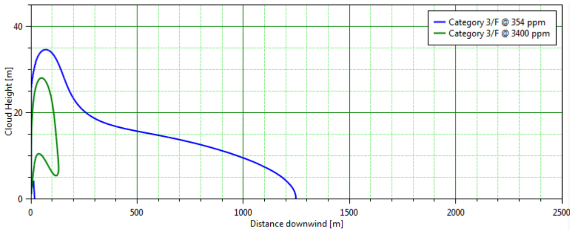
And the influence of the release direction



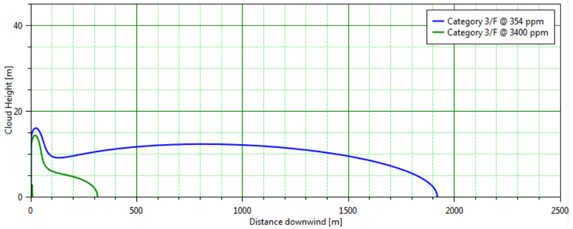
Horizontal release



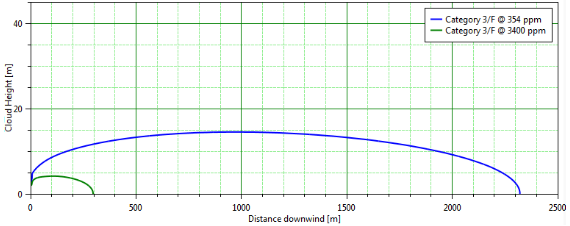
Vertical release



45° up



45° down

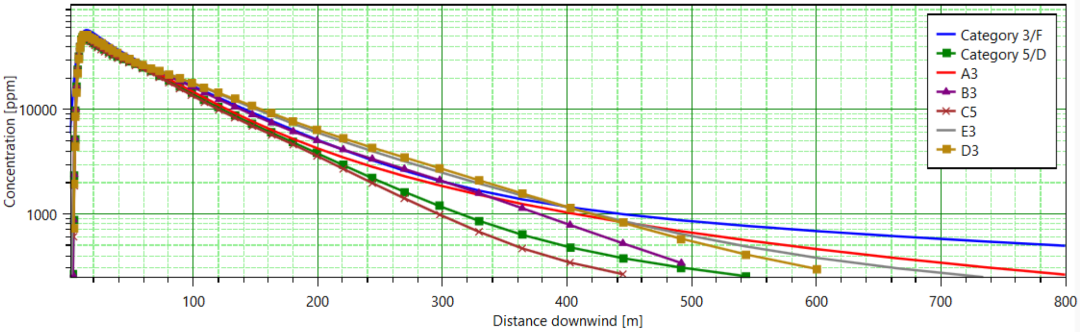


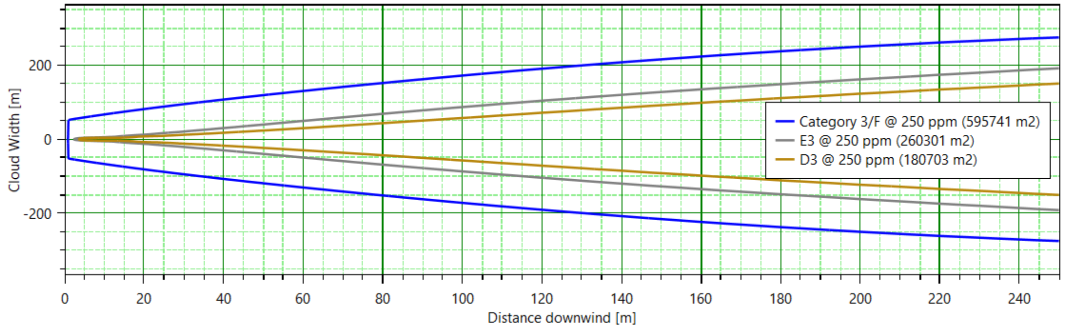
Ground impact

Analysis of the computed scenarios

Ammonia concentration along distance

- 16,5 mm release
- Several wind profiles
- Concentration in the release surrounding
  - > 10 000 ppm
- Near the limit of the site
  - Thousands of ppm
- Sensors technology in accordance
- Width of the cloud dependant of the distance





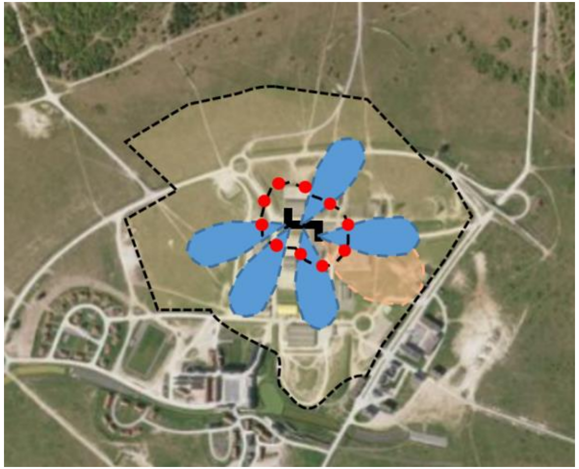
Cloud position

Hi-concentration case

- 30 000 ppm iso-concentrations
- Cloud plotting on the map
- Distance between detection point dependant on the distance ➔ 10 sensor points

Low-concentration case

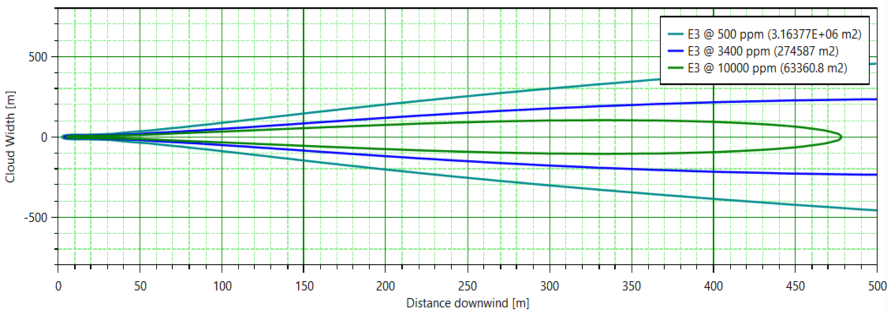
- 500 ppm iso-concentration
- Cloud plotting on the map
- Distance between detection point dependant on the distance ➔ 9 sensor points



Verification of the proposed mesh

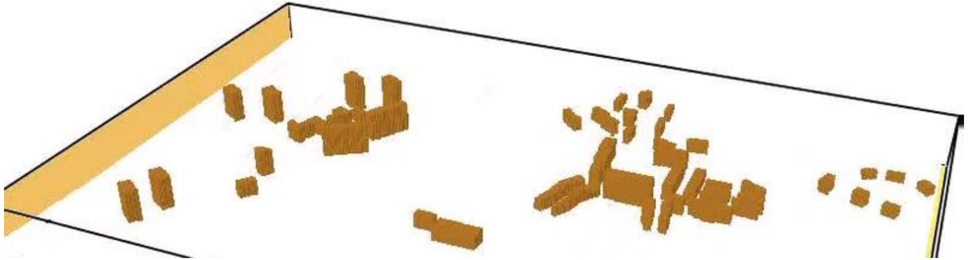
First set, other wind profile and release direction with a Gaussian model

- Higher and lower ambient temperature
- Non modelled wind profiles

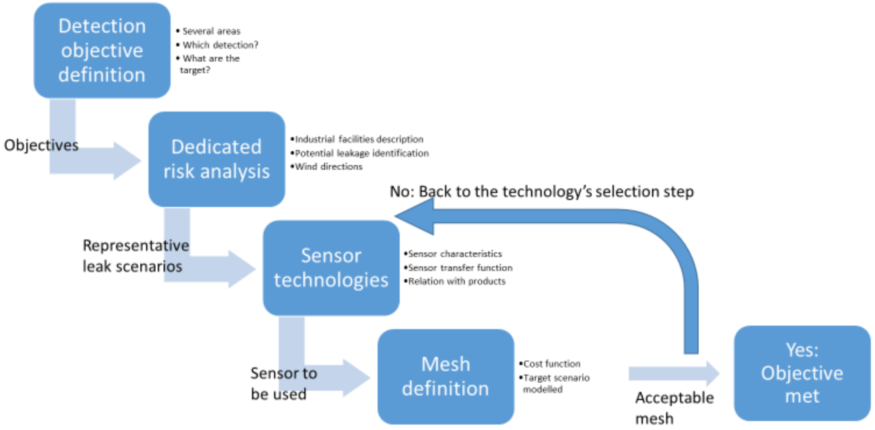


Second set, based on 3D CFD model

- Comparison free field vs real case
- Cloud concentration modified
- Verification should consider the influence of obstacle on lethal distance
  - Minimum flow rate to be considered is higher



Synthesis



Designing a sensor mesh implies

- Determining the detection strategy
- Achieving a dedicated risk analysis
- Having some knowledge on sensor
- Using numerical model and being aware of their advantages and limits