LAND-USE PLANNING REGULATIONS IN FRANCE AFTER THE TOULOUSE DISASTER

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1. AZF disaster

2. Land-use planning regulations
   - New approach of risk analysis in safety reports
   - Probabilistic safety assessment methods
   - Implementation of Technical Risk Prevention Plans

3. Current issues for probabilistic safety assessment

4. Conclusions
AZF DISASTER
Detonation of 200-300 tons of AN

Cause unclear: contamination of off-spec AN with sodium salt of dichloroisocyanuric acid (SDIC) but wht about the initiator?

Consequences
- 30 deaths / 3,000 injured people
- 500 houses inhabitable
- 3 billions dollars of damage

Big psychological/mediatic impact

Main problem: proximity of industrial sites and the urban vicinity
LAND-USE PLANNING REGULATIONS
NEW APPROACH OF RISK ANALYSIS IN FRANCE

Before 2003: deterministic approach based on maximum consequences → intensity of effects

Revision of the approach of risk analysis in safety reports

- Will to **harmonize** risk analysis approaches
- Will to develop a **probabilistic approach** in order to better appreciate the risks as a complement of the deterministic approach
- Integration of the facility in a geographic, economical and social **context** (LUP)

After 2003: probabilistic approach with the study of all representative scenarios → intensity, gravity, probability, risk, alea
DEFINITIONS

Probability: frequency with which an accident may occur during the lifetime of an installation

Gravity: effects of an accident on the population

Risk: probability of occurrence of an accident combined with its gravity

Alea: probability that an accident creates effects of a given intensity, and over a determined period of time at a given point of the territory
NEW APPROACH OF RISK ANALYSIS IN FRANCE

1. Identification of hazards
2. Characterisation of main hazards
3. Reduction of the main hazards
4. Learning from industrial accidents
5. Preliminary risk analysis
6. Detailed risk analysis
NEW APPROACH OF RISK ANALYSIS IN FRANCE

7. Evaluation of the intensity of accidents
8. Assessment of the probability of accidents
9. Determination of the potential consequences for people
10. Classification of the scenarios into the national matrix
EXAMPLE: BUND FIRE

Evaluation of the intensity of effects
- 3 kW/m², 5 kW/m², 8 kW/m²

Assessment of the probability
- one of the possible scenario leading to a bund fire is a tank failure
- assuming a E probability level

Determination of the potential consequences for people
- assuming there are 5 people in the 8 kW/m² zone

Classification of the scenarios into the national matrix
## INTENSITY OF THE EFFECTS

- **3 types of effects with 3 intensity levels**

<table>
<thead>
<tr>
<th></th>
<th>THERMAL EFFECTS</th>
<th>OVERPRESSURE EFFECTS</th>
<th>TOXIC EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5% LETHAL EFFECTS</strong></td>
<td><strong>8 kW/m²</strong></td>
<td>200 mbar</td>
<td>LC 5%</td>
</tr>
<tr>
<td></td>
<td>(1 800 kW/m²)⁴/₃(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1% LETHAL EFFECTS</strong></td>
<td>5 kW/m²</td>
<td>140 mbar</td>
<td>LC 1%</td>
</tr>
<tr>
<td></td>
<td>(1 000 kW/m²)⁴/₃(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IRREVERSIBLE EFFECTS</strong></td>
<td>3 kW/m²</td>
<td>50 mbar</td>
<td>IET</td>
</tr>
<tr>
<td></td>
<td>(600 kW/m²)⁴/₃(s)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# GRAVITY LEVELS

- **Number of people in each dangerous areas outside the facility**

<table>
<thead>
<tr>
<th></th>
<th>5% LETHAL EFFECTS</th>
<th>1% LETHAL EFFECTS</th>
<th>IRREVERSIBLE EFFECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISASTROUS</td>
<td>&gt; 10</td>
<td>&gt; 100</td>
<td>&gt; 1 000</td>
</tr>
<tr>
<td>CATASTROPHIC</td>
<td>1 to 10</td>
<td>10 to 100</td>
<td>100 to 1 000</td>
</tr>
<tr>
<td>MAJOR</td>
<td>1</td>
<td>1 to 10</td>
<td>10 to 100</td>
</tr>
<tr>
<td>SERIOUS</td>
<td>0</td>
<td>1</td>
<td>1 to 10</td>
</tr>
<tr>
<td>MODERATE</td>
<td>0</td>
<td>0</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>
Tank failure

Operational/internal causes

- Pressure
- Operator error
- Defective equipment
- Internal corrosion
- Wrong in line equipment
- Landslide
- Earthquake
- Flooding

E probability level

External causes

- Temperature high/low
- External corrosion
- Impact
- External loading
- Erosion

OR

Tank failure
## Qualitative Probability Levels

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>D</th>
<th>C</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E</strong></td>
<td>Extremely unlikely scenario</td>
<td>Realistic but unlikely scenario</td>
<td>Improbable scenario</td>
<td>Probable scenario</td>
<td>Usual scenario</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>Not impossible considering the current knowledge, but it hasn’t happened anywhere in the world</td>
<td>Not impossible but it hasn’t happened in a nearby industry</td>
<td>Already happened in a nearby industry in the world</td>
<td>Already happened (or supposed to have happened) during the lifetime of the facility</td>
<td>Already happened (possibly several times) during the lifetime of the facility</td>
</tr>
</tbody>
</table>

- **E** Extremely unlikely scenario
- **D** Not impossible considering the current knowledge, but it hasn’t happened anywhere in the world
- **C** Improbable scenario
- **B** Probable scenario
- **A** Usual scenario

**10^{-5}/year**  | **10^{-4}/year**  | **10^{-3}/year**  | **10^{-2}/year**  |  

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**IRSN**
<table>
<thead>
<tr>
<th>PROBABILITY</th>
<th>GRAVITY</th>
<th>E</th>
<th>D</th>
<th>C</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISASTROUS</td>
<td>NO / MMR2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>CATASTROPHIC</td>
<td>MMR1</td>
<td>MMR 2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>MAJOR</td>
<td>MMR1</td>
<td>MMR 1</td>
<td>MMR 2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>SERIOUS</td>
<td>MMR1</td>
<td>MMR 1</td>
<td>MMR 2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>MODERATE</td>
<td>MMR1</td>
<td>MMR 1</td>
<td>MMR 2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
TECHNOLOGICAL RISK PREVENTION PLANS

Mapping of aleas using rules to combine probability levels of several accidents (can come from several operators’ facilities) at a given point

Vulnerability studies?
TECHNOLOGICAL RISK PREVENTION PLANS

**Reduce the risk** at its root source

Adopt **protective measures** to reduce the exposition of the population

Define **construction rules** or zones with their own land-use planning:
- expropriation
- relinquishment
- pre-emption

**Communicate** with the population
CURRENT ISSUES
FOR
PROBABILITY SAFETY ASSESSMENT
BOW-TIE REPRESENTATION

SCENARIOS

Failure tree

Events tree

Prevention

Barriers

Protection

UE 1

UE 2

UE 3
CuE

UE 5

UE 6

UE 7
CuE

IE

AND

OR

SCE

CE

DP

ME

ME

ME

ME

ME

ME

ME

ME

DP

IRSN
“SEMI-QUANTITATIVE” METHOD

**Principles**
- allocate qualitative probability levels (A to E) to initiating events
- assign qualitative probabilities of failure (SIL 1 to 3) to safety barriers using criteria

**Benefits**
- simple and comprehensive method
- quick evaluation

**Limits**
- “order of magnitude” method
- lack of justification for the frequencies of initiating events
“SEMI-QUANTITATIVE” METHOD

LPG storage tank BLEVE

- Flange leak
- Pressure relief device leak
- Pump leak
- Compressor leak
- Pipeline leak
- Loading/unloading arm leak (road tanker)
- Loading/unloading arm leak (tank wagon)

Jet fires

- BLEVE of a LPG storage tank
  - Fire ball
  - Overpressure
  - Missiles

Missiles

Probability level?
“QUANTITATIVE” METHOD

Principles
- allocate “precise” probabilities directly to central events using databases (Purple Book, HSE, etc.)
- assign “precise” probabilities of failure to safety barriers

Benefits
- “precise” values

Limits
- old values of probability (30 years or more!)
- ignores the influence of lacking/additional prevention barriers
LOC DATABASES USED IN EUROPE

- Purple Book (TNO):
  - data often based on rare and old data, combined with expert judgement
  - consensus between industry, authorities and government
  - definition of default values

- FRED database (HSE):
  - similar situation as Purple Book
  - some failure rates are given as an upper, median and lower value
  - good starting point for the derivation of failure frequencies, but how?
LOC DATABASES USED IN EUROPE

Loss of Containment (LOC)

- Many databases!
- Kind of failure causes not always clear!
- Some old values that don’t take into account safety improvements!

<table>
<thead>
<tr>
<th>Equipment</th>
<th>CPR 18E “Purple book” (RIVM)</th>
<th>Failure Rates and Event Data (HSE)</th>
<th>Handboek kanscijfers (AMINAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>$10^{-4}$/year to $10^{-5}$/year</td>
<td>$3.10^{-5}$/year (failure of casing)</td>
<td>$10^{-4}$/year</td>
</tr>
<tr>
<td>Pressure vessel</td>
<td>$5.10^{-7}$/year</td>
<td>$4.10^{-6}$/year (BLEVE)</td>
<td>$10^{-7}$/year</td>
</tr>
<tr>
<td>Atmospheric tank</td>
<td>$5.10^{-6}$/year</td>
<td>$5.10^{-6}$/year</td>
<td>$5.10^{-6}$/year</td>
</tr>
</tbody>
</table>
Pressurized vessel catastrophic rupture

- Earthquake
- Flood
- Missile impact
- Fire engulfment
- Aircraft impact
- Lightning
- Vehicle impact
- Overfilling
- No operator action
- Pressure relief system fails
- Pressure > design pressure

OR

External damage

AND

Overpressurization

OR

Vessel failure

Inadequate corrosion protection

- Inadequate inspection
- Corrosion
- Defects developing in service

AND

Defective design

- Defective materials
- Defective manufacturing
- Initial test fails to identify defect

OR

Fatigue

AND

Defective materials

OR

Defective manufacturing

AND

Defective design

OR

Initial test fails to identify defect

Purple Book

FRED (HSE)
**INTERESTING WORK**

- **J.R. TAYLOR (for RIVM):**
  - definition of baseline failure frequencies
  - combination with modification factors, according to the standards of design, construction, operations, maintenance, operating conditions
  - more recent and varied data
  - ... but report is not finalized and not in the public domain
FAILURE DATABASES USED IN EUROPE

Safety barriers

- Many databases, often not relevant for the chemical industry!
- Difficulties to find details about the fluid considered, the working environment ...
- Difference between values from well-known databases could be greater than 100 for a pressure sensor!

<table>
<thead>
<tr>
<th>Equipment</th>
<th>“Red Book”</th>
<th>LEES</th>
<th>OREDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature sensor</td>
<td>0,018/y</td>
<td>0,88/y</td>
<td>0,1/y</td>
</tr>
<tr>
<td>Pressure sensor</td>
<td>0,0055/y</td>
<td>1,4/y</td>
<td>0,019/y</td>
</tr>
<tr>
<td>Level sensor</td>
<td>0,0042/y</td>
<td>0,02/y to 0,002/y</td>
<td>0,055/y</td>
</tr>
</tbody>
</table>
2003: IRSN was called upon by the French Ministry of the Environment to carry out a PSA study of a LPG distribution site using the probabilistic approach applied in the nuclear industry.
LEARNING FROM THE NUCLEAR INDUSTRY

Nuclear safety approaches can be applied to the chemical industry with strong benefits:

- prioritize actions to be carried out to improve safety
- conduct generic studies to evaluate the benefits of one safety barrier over another one

PSA is a powerful tool but it requires credible data for reliability and failure, not available in generic failure databases.
LEARNING FROM THE NUCLEAR INDUSTRY

Another initiatives of IRSN:

- Critical analysis of a hazard and reliability database managed by a chemical operator and conclusions presented to the French Ministry of the Environment

- Development of a national database for the LPG industry using the nuclear industry methodology for collecting and analysing data, to provide more precise and representative failures rates for main safety equipments
CONCLUSIONS
2003 risks’ law leads to a better approach of the risks of the high risk facilities in France but ...

... there is still a lot of work in probabilistic assessment methods:

- **Unknown origins of the available data** (some reports are not in the public domain for instance)
- **No common methodology to organize a feedback** at a national or international level
- **No common definitions and terminology**: for example, a catastrophic failure has a different meaning for TNO and HSE
- No common definition of the **boundary of equipments**
- **Unknown failure causes**
- Unknown **nature and number of safety barriers included in failure rates**
Potential solutions

At the present time:
- set up an international **working group** of experts
- organize data in a coherent way in order to obtain **“standard values”** with advice for their relevant use

In the future:
- develop a common methodology to introduce **modification factors** in order to take into account lacking/additional provisions (need generic fault trees)
- **organize a coherent feedback through national associations** (CSChE, AIChE, EFIC, UIC, etc.): one motivation for operators could be that with a better feedback, it is likely failure frequencies will be lower!
THANKS A LOT
FOR YOUR ATTENTION

DO YOU HAVE ANY QUESTIONS?