INDUSTRIAL RISK ASSESSMENT FOR ROMANIAN SEVESO II SITES (RESULTS OF AN EC TWINNING LIGHT PROJECT)

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In 2009 the European Commission launched a Twinning Light Project called "Support for improving the General Inspectorate for Emergency Situations capacity in assessment of the risks/major accidents effects" for the respective authority of Romania. The project was awarded to Austria and performed during the first half of 2010 in cooperation between TUV Austria and the representative of the Austrian federal authority for matters of the Seveso II Directive, Dr. Michael Struckl/ Federal Ministry of Economics.

The main goal of the project was to develop, apply and disseminate a methodology for risk assessment of Seveso sites under consideration of the specific conditions present in Romania, i.e.

- Low to medium degree of experience of Romanian operators regarding risk assessment
- Limited available financial resources of operators and authorities, i.e. no general usability of high-end commercial software
- Past focus on mitigation rather than on prevention of major accidents

During the project the partners discussed the different available qualitative, quantitative and deterministic approaches, taking into account the present Romanian situation. Finally, the following methodology was considered to be suitable:

- Qualitative hazard identification by HAZOP and/or the "Haferkamp"-Checklist (depending on the complexity of a unit)
- Quantitative assessment of single process-related scenarios using LOPA
- Consequence Analysis of reasonably conceivable scenarios (with examples provided in a checklist) – to be used for internal (and external) emergency planning and land-use planning, as well as for the determination of required mitigation measures
- Consequence analysis of (almost) worst-case scenarios for external emergency planning

The details and background of the methodology are described in this paper.

KEYWORDS: Seveso II, LOPA, Romania

INTRODUCTION

SEVESO II DIRECTIVE

The Directive 96/82/EC [1] (the "Seveso II – Directive" named after the well-known accident in Italy in 1976) is aimed at the prevention of major accidents involving dangerous substances and at the mitigation of such events. The scope of the Directive is defined by the presence of defined quantities of certain dangerous substances (named individually or by categories); currently approximately 10.000 establishments [2] in the European Union currently fall under the requirements of this specific legislation.

In order to comply with these targets the Directive comprises several objectives, in particular that:

- appropriate safety technology is in place
- an appropriate safety management system is in place
- the mitigation of accident consequences is supported by emergency response systems (on-site and off-site)
- the accident mitigation is also reflected by measures of land-use planning around the site and information is provided to the public likely to be affected by an accident
- the Competent Authority organizes inspections in compliance with the Directive's requirements.

The operator of an establishment falling under the Seveso II Directive has the obligation to demonstrate compliance by submitting a safety report (for the purpose of this paper the differentiation between so-called upper-tier and lower-tier sites according to different substance thresholds present at the establishment is neglected). This documentation serves not only as a demonstration that all necessary measures are in place but also as a basis for the supporting activities as mentioned before: emergency response and land-use planning.

The European Commission has published a guidance document [3] which clearly underlines the fact that it is not intended to cover every aspect of the safety concept in the report: "demonstrate" is intended in its meaning of "justify" or "argue the case" but not "provide" an absolute proof.

In this respect a risk analysis carried out for Seveso II compliance needs on the one hand to seek to identify only relevant hazards and establishment parts and reflect on the sufficiency of the measures taken, but on the other hand, to allow a correct and thorough judgment. In fulfilling this intention the abilities and competencies of the Competent Authority must be taken into account; this objective depends very much on national factors and limitations.

GOALS OF THE TWINNING PROJECT

In 1998 the European Union launched the so-called Twinning programme as one of the principal tools of Institution Building accession assistance. Twinning aims to help beneficiary countries in the development of modern and efficient administrations, with the structures, human resources and skills needed to implement the acquis communautaire to the same standards as Member States. In 2009 the European Commission launched a Twinning Light Project called "Support for improving the General Inspectorate for Emergency Situations capacity in assessment of the risks/major accidents effects" for the respective authority of Romania. The project was awarded to Austria and performed during the first half of 2010.

In the progress reports on achieving the targets of European Union legislation produced by the European Commission a major conclusion was that Romania was generally meeting the requirements. But although Romania made progress as regards administrative capacity, both in terms of the recruitment and training of personnel, further strengthening was required in particular at regional and local level. Lack of proper co-ordination between national, local and the relatively newly established environmental authorities remained an area of serious concern.

A major challenge in this respect is represented by the implementation of the Seveso II Directive. Romania transposed the Directive in various parts of national legislation, but the number of the establishments (around 300) and lack of appropriate expertise within the competent authorities require a substantial effort in order to cover all the aspects of the Directive's requirements. In particular it requests a number of specific abilities from the Competent Authority personnel involved, which belongs to the General Inspectorate for Emergency Situations. Bearing in mind that the respective institutional framework had to be modified and the personnel from central and county level were mostly newly employed, it was necessary to develop risk analysis tools that provide a proper and practical assessment of the submitted safety reports. The intention was therefore to develop a tool which was on the one hand composed of components of state of the art of risk analysis and on the other hand could be presented in a relatively short time. Therefore the main goal of the project was to develop, apply and disseminate a methodology for risk assessment under consideration of the specific conditions present in Romania, i.e.

- Low to medium degree of experience of Romanian operators regarding risk assessment
- Limited available financial resources of operators and authorities, i.e. no general usability of high-end commercial software
- Past focus on mitigation rather than on prevention of major accidents.

A methodology was developed that consisted of individual proven components but was understandable for all of the involved persons with a good general technical knowledge and competencies in the field of major accident risk analysis.

METHODOLOGY FOR INDUSTRIAL RISK ASSESSMENT

BACKGROUND INFORMATION – THE AUSTRIAN CONCEPT

In Austria – a country with about 150 Seveso establishments – the focus of industrial risk assessment in the past was characterized by a major emphasis on prevention measures, with emergency planning and land-use planning based on a consequence analysis of "reference scenarios" as additional tools. The adequacy of prevention measures was determined in a qualitative way. This approach to risk assessment in the context of the Seveso II regime was highly influenced by the German approach and differs completely from the full QRA approach, as used extensively in the UK and the Netherlands.

However, quantitative methodologies like the Layer-of-Protection-Analysis (LOPA) have been used more frequently for single scenario assessment during recent years. Also in general, probabilistic approaches for risk assessments in diverse applications appear increasingly in new European/International standards. Due to all of these facts it is seen as a requirement of technical progress to include some quantitative aspects in the methodology used for risk assessment, and this can be done by using a quantitative determination of the adequateness of barriers (safeguards) against single scenarios with possible severe consequences. Based on the Austrian authorities' risk assessment culture, a full QRA approach was not considered appropriate. This was further backed up by the fact that no legal risk tolerability criteria exist in Romania.

METHODOLOGY FOR ROMANIA

Independently from the Austrian approach, different qualitative, quantitative (also full QRA) and deterministic approaches were discussed and taken into account during the Twinning Project activities, especially with regard to the present Romanian situation, i.e. limited degree of experience, limited financial resources and past focus on mitigation activities. Finally the methodology shown in Figure 1 was considered to be suitable. In the following, the main parts of this methodology as given in [4] are described in more detail.

Hazard Analysis by HAZOP and/or Checklist

The first step is the selection of an appropriate (state of the art) methodology for systematic identification of unit/equipment specific hazards. The systematic approach aims to produce a detailed identification of hazards. In contrast

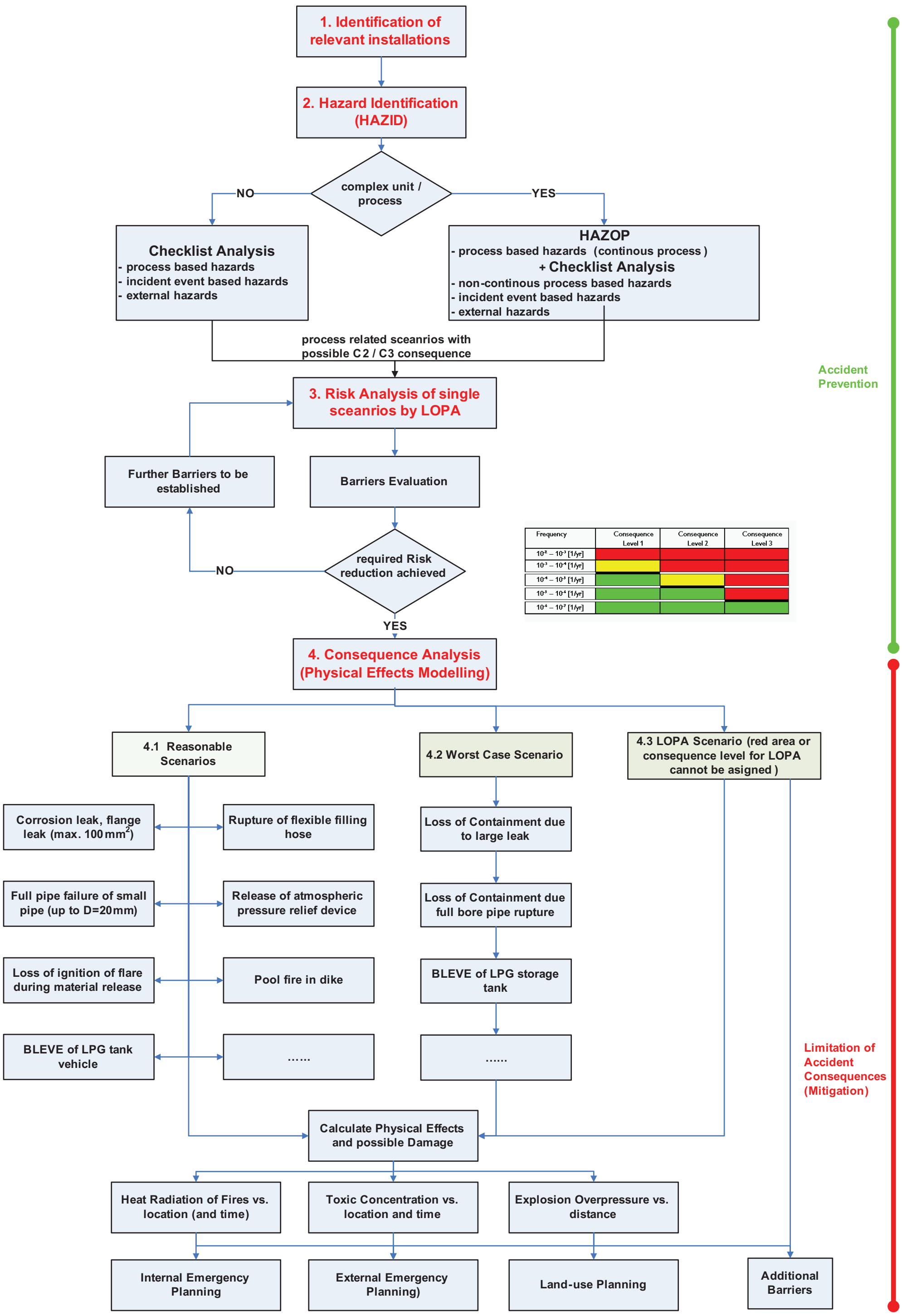

Figure 1. Risk assessment methodology schema

to a systematic methodology, a pure brainstorming approach might miss major hazards by chance. An important focus of the hazard analysis is to consider the prevention measures which ensure that an accident caused by process deviations is avoided as far as possible.

Appropriate methodologies for hazard analysis are "Checklist" and "HAZOP". The selection of the method or combination of the methodologies basically depends on the complexity and the mode of operation of a unit, as shown in Figure 2. The Checklist used in this context is a

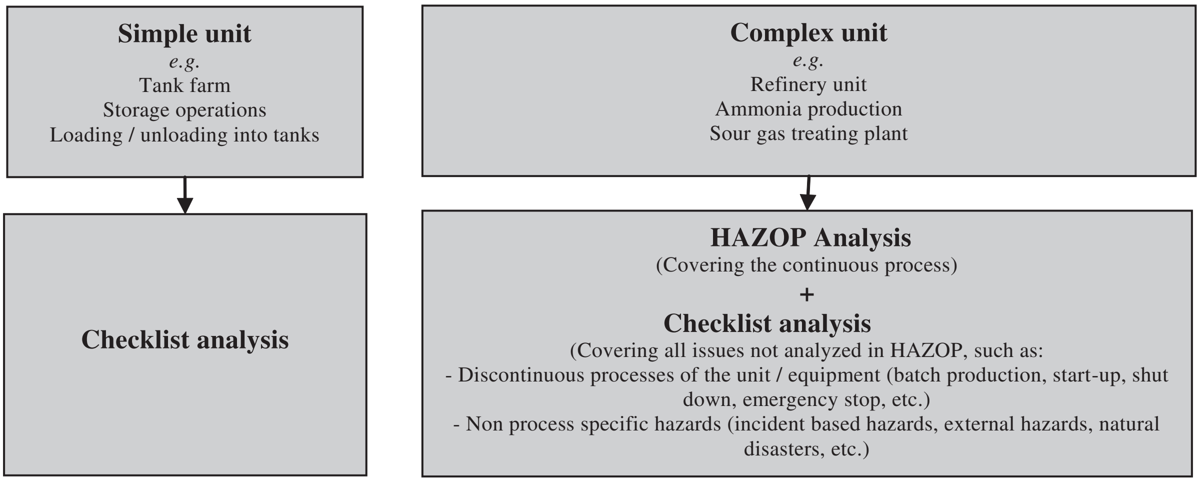

Figure 2. Hazard identification methods

modification of the so-called "Haferkamp"-Checklist, which was developed in Germany especially for risk analysis of Seveso establishments [5].

The checklist is sub-divided in three parts: process based hazards, incident event based hazards and external hazards, as shown in Table 1, Table 2 and Table 3. Years of experience of application show that the Checklist based brainstorming is highly effective for analysing relevant unit-specific risks (i.e. the prompts in the checklist stimulate the identification of hazards).

For more complex process units (e.g. refinery units) the hazard analysis of process related hazards is recommended to be conducted by the HAZOP method. In such cases only those hazards which are not covered by the HAZOP shall be analysed using the checklist methodology (e.g. external hazards, some incident event hazards, etc.).

Quantitative Risk Assessment of Single Process Related Scenarios

Harmful process-related single scenarios identified during Checklist or HAZOP analysis shall be passed further to quantitative risk analysis (using LOPA) to decide on the adequacy of safeguards.

The risk of a "single scenario", for which LOPA shall be applied, relates to the likelihood that an initiating event develops to its worst credible outcome. Example: Overfilling of a column leads to overpressure, column rupture, loss of containment (LOC) of flammable material, a vapour cloud, in case of ignition to an explosion or a flash fire, and thus, to harm to people due to the blast pressure, heat radiation, missiles, etc.

The term "process related" refers to scenarios which are initiated by foreseeable deviations from the intended process (e.g. malfunctions of control loops, failure of rotating equipment, maloperation of valves, changes of feedstock materials, loss of utilities, operator error, etc.). Scenarios based on unspecific causes, e.g. corrosion leakage of vessel or pipework, are not considered quantitatively (as in a full QRA study). Within the developed approach, the latter scenarios are treated in a general way, e.g. corrosion related preventive considerations (equipment inspection, material selection, RBI) as well as by the required deterministic consequence analysis.

The basic LOPA principle [6] is that depending on the severity of the worst credible consequence, a certain number and/or a certain quality (characterized by the probability of failure on demand) of barriers are required to end up with a tolerable/acceptable risk for the single scenario. The required barriers are derived from the risk matrix in Figure 3, which comprises three areas:

- Red area – intolerable risk – scenarios with a frequency in this area are not tolerable, i.e. additional safeguards to lower the scenario frequency have to be established.
- Yellow area – ALARP – reducing the risk as low as reasonable practicable (achievable): the risk level is considered to be "tolerable", on the condition that it is reduced to a point beyond which further expenditure is disproportionate to the risk reduction improvement gained, taking into account the cost and the fact that internationally accepted standards have been applied for risk control and reduction. The ALARP concept shall only be applied for existing establishments. The thick black line represents the limit line to be achieved for all single scenarios for new establishments.
- Green area – acceptable risk – no further risk reduction is required.

The origins of the values used to derive the risk matrix are as follows:

- 10^{-6} [1/yr] general accepted individual risk as often used and applied in medicine
- 10^{-5} [1/yr] mean statistical value of a fatal workplace accident;
- $10^{-3} - 10^{-4}$ [1/yr] mean statistical value of hospitalization after a workplace accident.

Table 1. Checklist – process based hazards

General process based hazards	
1.	**Loss of containment of dangerous substance due to mechanical overstress of equipment**
1.1	Design error
1.2	Manufacturing and assembling error
1.3	Exceeding allowable pressure range
1.4	Exceeding allowable temperature range
1.5	Degradation due to corrosion, erosion, wear
1.6	Degradation due to vibration/fatigue
1.7	Weak point at flange, valve, seal, impulse connection, etc.
1.8	Bearing failure
1.9	Dismantling of moving components
2.	**Loss of containment of dangerous substance due to uncontrolled transfer to unsuitable equipment**
2.1	Failure in chemical reaction
2.2	Failure in substance flow
2.3	Control system failure
2.4	Failure of energy/utility supply (electric power, pressurized air, etc.)
3.	**Loss of containment of dangerous substance due to uncontrolled transfer to unsuitable equipment caused by human error**
3.1	Operating error during normal operation
3.2	Error during startup or shut-down
3.3	Error during maintenance/repair works
3.4	Error during internal transport of dangerous substances
4.	**Loss of containment of dangerous substance due to explosive mixture inside equipment and ignition**
4.1	Creation of explosive mixture
4.1.1	Flammable/explosive substance present due to error
4.1.2	Explosive atmosphere due to leakage
4.1.3	Explosive atmosphere due to human error
4.1.4	Explosive atmosphere due to malfunction of control system
4.1.5	Local explosive atmosphere
4.1.6	Explosive atmosphere due to loss of inerting substance
4.2	Ignition of explosive mixture inside equipment
4.2.1	Hot surface, friction, mechanical sparks
4.2.2	Flame, hot gases, adiabatic compression
4.2.3	Chemical reaction, ignition effective material (e.g. FeS)
4.2.4	Electrostatic discharge, equalizing current
4.2.5	Electric sparks
4.2.6	Electromagnetic waves, ultrasonic or ionizing radiation
5.	**Ignition of an flammable substances or an explosive atmosphere, following a loss of containment due to general hazards 1, 2 or 3**
5.1	Hot surface, friction, mechanical sparks
5.2	Flame, hot gases, adiabatic compression
5.3	Chemical reaction, ignition effective material (e.g. FeS)
5.4	Electrostatic discharge, equalizing current
5.5	Electric sparks
5.6	Electromagnetic waves, ultrasonic or ionizing radiation

As a comparison to international values, the Health & Safety Executive (UK) published the following statement in the so-called R2P2 document [7]: "Concerning the tolerability of risks in nuclear power stations, we suggested that an individual risk of death of one in a thousand per annum should on its own represent the dividing line between what could be just tolerable for any substantial category of workers for any large part of a working life, and what is unacceptable for any but fairly exceptional groups. For members of the public who have a risk imposed on them 'in the wider interest of society' this limit is judged to be an order of magnitude lower – at 1 in 10 000 per annum". Since LOPA does not deal with the total individual risk, but only with the risk due to single scenarios, the corresponding threshold values are considered to be one to two orders of magnitude lower.

Table 2. Checklist – incident event based hazards

Incident event based hazards	
1.	**Damage due to fire/toxic emission inside the unit**
1.1	Insufficient fire protection
1.2	Dikes and retention volumes to small
1.3	Insufficient discharge of released substance from unit area
1.4	No limitation of released substances
1.5	Insufficient emergency exits for personnel
2.	**Damage due to fire/explosion outside the unit**
2.1	Insufficient distance to other units
2.2	Insufficient constructive protection between units
3.	**Damage due to failure of measures against fire/toxic effects**
3.1	Failure of fire alarm/fire detection system
3.2	Insufficient fire fighting equipment
3.3	Failure of stationary fire fighting equipment
3.4	Insufficient access to relevant area
3.5	Insufficient fire fighting organization
3.6	Injury of emergency forces due to physical/chemical scenario effects
3.7	Insufficient training of emergency forces
4.	**Damage due to failure of explosion limiting measures**
4.1	Failure of (gas/concentration) detection systems
4.2	Failure of limitation measures for released substances
4.3	Insufficient distance
4.4	Failure of explosion mitigation measures (blast wall, bunker, explosion flaps/doors, etc.)
5.	**Damage due to failure of substance concentration measurement**
5.1	Failure of gas/pollutant detection system
5.2	Failure of leakage detection system at surface or in soil
5.3	Failure of substance detection system in sewage/waste water system
6.	**Damage due to failure of blowdown/retention systems**
6.1	No measures to ensure decreasing of dangerous concentration
6.2	Porous surface at release area
6.3	Insufficient separation of released toxic or water-hazardous substances
6.4	No separation of water-soluble or solid substances from exhaust gas
6.5	No limitation of toxic clouds (e.g. by water curtain)
7.	**Damage due to failure of substance elimination**
7.1	Insufficient systems for containing dangerous substances
7.2	No conditioning systems for dangerous substances
7.3	No thermal substance elimination/no flare
7.4	No controlled disposal of dangerous substances/waste

Accidents with consequence levels C2 and C3 are considered to be major accidents within the scope of the Seveso II directive (in case that dangerous materials are involved).

To assess a scenario by LOPA, a previous rough estimation of the worst credible consequences is required. Usually this is done by expert judgment and not by doing a detailed consequence analysis.

The methodology document [4] includes Annexes which list standardized valued of frequencies of initiating events, PFDs (Probability of Failure on Demand) of protection layers, etc. By using these values, the methodology can be applied consistently by different users.

If the LOPA of a scenario shows that the barriers for a process related scenario are not sufficient, additional safeguards have to be established by the operator within a time schedule agreed upon with the authorities.

Consequence Analysis of Accidental Scenarios

The term consequence analysis refers to the detailed analysis of the consequences resulting from "LOC" (loss of containment) or fire/explosion scenarios of dangerous materials. This mainly concerns dispersion of toxic materials, thermal radiation and explosion overpressures which endanger human life and/or the environment.

The following scenarios shall be analyzed:

(A) Process-related scenarios with the frequency above the limit line according to LOPA, as well as those scenarios for which rough consequence estimation

Table 3. Checklist – external hazards

External hazards	
1.	**Damage due to external (natural) loads**
1.1	Insufficient protection against to flooding
1.2	Insufficient protection against earthquake or landslide
1.3	Insufficient protection against windstorm
2.	**Damage due external heat load or energy impact**
2.1	Insufficient protection against external fire
2.2	Insufficient protection against lightning strike or hazards due to high-voltage line
2.3	Insufficient protection against failure of pipelines containing dangerous materials, which are not part of the unit (est.) but are crossing the establishment's area
3.	**Damage due to solid body impact**
3.1	Insufficient protection against impact due to transportation means (vehicles, etc.) and nearby objects (e.g. corrosion caused collapse of adjacent equipment which is out of service, trees, etc.)
3.2	Insufficient protection against missile impact due to external explosion
4.	**Damage due to intrusion of unauthorized persons**
4.1	Insufficient protection against access of unauthorized persons
4.2	Insufficient protection of critical systems against intervention of unauthorized persons (e.g. no restriction to modify a programmable safety system)
4.3	Insufficient management of contractor services in unit area
5.	**Insufficient emergency operations due to external influences**
5.1	Lack of dedicated access for emergency services/vehicles
5.2	Emergency and protection equipment and special extinguishing/neutralizing media not available
5.3	Lack of cooperation with external emergency forces
6.	**Inadequate behavior of emergency forces (internal and external)**
6.1	Insufficient training (e.g. concerning treatment of materials) of emergency forces
6.2	Inadequate recognition and evaluation of hazards
6.3	No/insufficient alarm plan

Frequency	**Consequence Level C1**	**Consequence Level C2**	**Consequence Level C3**
10^{-2} – 10^{-3} [1/yr]	RED	RED	RED
10^{-3} – 10^{-4} [1/yr]	YELLOW	RED	RED
10^{-4} – 10^{-5} [1/yr]	GREEN	YELLOW	RED
10^{-5} – 10^{-6} [1/yr]	GREEN	GREEN	RED
10^{-6} – 10^{-7} [1/yr]	GREEN	GREEN	GREEN
Human Consequence	1 or more persons on-site hospitalized for more than 24 hours; reversible short term health effect	1 fatality or irreversible health effect on-site; single person off-site hospitalized	Several fatalities or irreversible health effects on-site; fatality or irreversible health effect off-site
Environmental Consequence	Reversible environmental damage, local intervention of on-site and off-site forces.	Reversible environmental damage, supra-regional intervention required.	Massive environmental damage, possible irreversibility, supra-regional, national or international intervention required.

Colour designation	*RED: intolerable*	*YELLOW: ALARP*	*GREEN: acceptable*

Figure 3. LOPA risk matrix

(C1, C2, C3) can not be done without detailed analysis. For those scenarios with the frequency above the limit line, the analysis shall give more information to establish additional safeguards.

(B) Reasonable scenarios: These shall be used for on-site (and off-site) intervention planning, and probably for land use planning purposes (but there was no final decision on the issue during the project). Those scenarios might be (but are not necessarily limited to) the following:

- Vessel leakage (max. leak area size 100 mm^2) at a location which leads to the worst consequences due to physical and chemical properties;
- Pipe leakage, leak area size $= 0.01 \cdot D^2$, max. 100 mm^2 – at a location which leads to the worst consequences due to physical and chemical properties (D refers to the pipe diameter in mm);
- Flange leak (leak area size $= 0.00035 \cdot D^{2,2}$) - at a location which leads to the worst consequences due to physical and chemical properties (D nominates the pipe diameter in mm)
- Full bore rupture of flexible loading hose
- Full bore rupture of a small pipe with diameter $\leq$ 20 mm – at a location which leads to the worst consequences due to physical and chemical properties
- Release from atmospheric relief device (maximum credible flow)
- Loss of ignition of a flare during release (maximum credible flow)
- Pool fire in a dike
- Pool fire in a tank
- BLEVE (Boiling Liquid Expanding Vapour Explsoion) of an LPG (Liquefied Petroleum Gas) tank vehicle
- BLEVE of an LPG tank in case of insufficient fire protection (i.e. no gas detectors, no heat protection insulation, no proper emergency services and equipment for tank cooling)
- Explosion in an explosives storage facility
- Warehouse fire

(C) Worst-case scenarios: These scenarios are considered to be useful for off-site emergency management. Examples for worst case scenarios are a large size release (e.g. diameter 100 mm or more) from tanks or storage vessels, the BLEVE of an LPG storage tank, the instantaneous rupture of a vessel, the full bore rupture of a pipe, etc.

Scenario selection is done deterministically for B) and C), reflecting the historic Romanian approach. A full probabilistic approach for consequence analysis scenario selection was considered to be too complex with respect to the existing Romanian conditions for risk analysis.

Is it important, to limit the selected scenarios to those which are representative for the unit under consideration and sufficient for the intended purposes.

For a unified approach, it is required that the values given in Table 4 shall be used as thresholds for physical effects of accidents (these values are considered to render also sufficient information for intervention purposes). In this context it has to be noted that:

- Outside of zone III no evacuation and intervention action is required, e.g. for toxic exposure

Table 4. Thresholds for physical effects

Accidental scenario	Zone I – mortality	Zone II – irreversible injury	Zone III – reversible injury
Toxic emission	AEGL 3 [A)]	AEGL 2 [B)]	AEGL 1 [C)]
Fire (stationary thermal radiation)	12,5 kW/m^2 [D)]	5 kW/m^2	2,5 kW/m^2
BLEVE/Fireball (instantaneous thermal radiation, max. duration 15 seconds)	radius of fireball	12,5 kW/m^2	4,5 kW/m^2
Flash fire (non-stationary thermal radiation)	LFL	$\frac{1}{2}$ LFL	4,5 kW/m^2
VCE (Overpressure)	300 mbar (structures) [E)] 450 mbar (open space)	70 mbar [F)]	30 mbar [G)]

A) AEGL 3 is the airborne concentration, expressed in ppm or mg/m^3, of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

B) AEGL 2 is the airborne concentration, expressed in ppm or mg/m^3, of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

C) AEGL 1 is the airborne concentration, expressed in ppm or mg/m^3, of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

D) first degree burns after 10 seconds of exposure

E) total destruction of buildings

F) partial destruction of buildings

G) slight injuries caused by glass fragments the maximum air concentration is considered to be in the range of the maximum allowable workplace concentration or lower.

- The AEGL (Acute Exposure Guideline Levels) threshold values were developed by the Enviromental Protection Agency (EPA) of the USA and give distinct concentration values for 10, 30, 60 minutes or 4 and 8 hours exposure time.
- Each scenario shall be analyzed for two different weather conditions. These shall be the least favorable, but possible weather condition and the normal/most frequent weather condition.
- For toxic emissions it was decided that for each threshold value and weather condition, the path and dimension of the toxic cloud shall be evaluated for at least three characteristic time intervals, e.g. 10, 30 and 60 minutes after the beginning of the release.

DISSEMINATION AND APPLICATION OF THE METHODOLOGY

The methodology was applied for different industrial sites within the project activities. This was done partly by teamwork with Romanian operators and authorities as well as Austrian experts (methanol production unit, PVC production unit), and partly by teamwork with Romanian authorities and Austrian experts (ammonia storage facility, LPG storage facility). The corresponding results were satisfactory.

The methodology was published by the Romanian project partners [4]. The dissemination to relevant central, regional and local authorities was done during dedicated project activities. The first dissemination to Romanian industry was done during a one-day conference in Bucharest in July 2010.

The Romanian "General Inspectorate for Emergency Situations" intends to get a mandatory status of application of the methodology by initiating a corresponding Ministerial Order (which has the status of a law). This would lead to a harmonized method of risk assessment for Seveso II establishments in Romania.

CONCLUSIONS

The main goal of the European project "Support for improving the General Inspectorate for Emergency Situations capacity in assessment of the risks/major accidents effects" was to develop, apply and disseminate a methodology for risks assessment under consideration of the specific conditions present in Romania, i.e. low to medium degree of experience of Romanian operators regarding risk assessment, limited available financial resources of operators and authorities, and the past focus on mitigation rather than on prevention of major accidents.

During the project the partners discussed the different available qualitative, quantitative and deterministic approaches (including full QRA), taking into account the present Romanian situation. Finally, the following methodology – a toolbox of different risk assessment techniques – was considered to be suitable:

- Qualitative hazard analysis by HAZOP and/or the "Haferkamp"-Checklist (depending on the complexity of a unit);
- Quantitative risk assessment of single process-related scenarios by usage of LOPA;
- Consequence analysis of reasonably conceivable scenarios (as provided as examples in a list) – to be used for internal (and external) emergency planning and land-use planning, as well as for the determination of required mitigation measures;
- Consequence analysis of (almost) worst-case scenarios for external emergency planning

The authors would especially like to express their wish that the application of this methodology leads to an increased level of industrial safety in Romanian industry as well as to a broader corresponding knowledge on risks and their prevention and mitigation.

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