Risk assessment in decision making related to land-use planning (LUP) as required by the Seveso II directive

Olivier Salvi, Didier Gaston

Risk assessment in decision making related to land-use planning (LUP) as required by the Seveso II directive

SALVI Olivier, GASTON Didier
INERIS, 60550 Verneuil-en-Halatte, France
Tel : +33 3 44 55 61 01, fax : +33 3 44 55 62 95, e-mail : olivier.salvi@ineris.fr

Introduction

The 1999 annual report from the European Environment Agency indicated that in spite of measures on major industrial accidents in force since 1984, the trend in accidents shows that many of the often seemingly trivial 'lessons learned' from accidents have not yet been sufficiently evaluated and implemented in industry's practices and standards.
It was confirmed by the recent accidents (Enschede in 2000, Toulouse in 2001) that have shown that disasters continue to occur throughout the EU despite of the efforts to control major accident hazards with Seveso I and Seveso II directives.
Moreover, a recent communication from the Commission (European Commission, 2002) indicates that the frequency of major accidents is estimated at about 3.10^{-3} per year if we consider the number of accidents reported in the accident database of the European Commission MARS (Major Accident Reporting System) versus the number of hazardous installations throughout the European Union.

So, controlling major accident hazards by reducing the risk on-site is not sufficient to promote a sustainable development for both industry and urban areas in the next decades. It is necessary to organise the settlement of industrial and urban areas with land-use planning (LUP).

This paper presents an approach to implement LUP in the context of the Seveso II directive[1]. In the first part, the requirements of the directive regarding LUP are given, and the use of LUP in a risk management policy is analysed. Then, in the second part, the authors describe the current situation in France, where LUP is applied for more than 10 years with an approach based on the evaluation of the consequences of major accident scenarios. In the third part, the authors share their thoughts to improve the LUP procedure by distinguishing a risk assessment phase and a negotiation phase involving the stakeholders.

1 LUP as part of a risk management policy

This chapter describe the requirement of the Seveso II directive and an analysis of the use of LUP as part of a risk management policy.

1.1 LUP in the Seveso II directive

The article 12 of the Seveso II directive requires that :
"Member States shall ensure that their land-use and/or other relevant policies and the procedures for implementing those policies take account of the need, in the long term, to maintain appropriate distances between establishments covered by this Directive and residential areas, areas of public use and areas of particular natural sensitivity or interest, and,

[1] Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances

in the case of existing establishments, of the need for additional technical measures in accordance with Article 5 so as not to increase the risks to people."
Even if the directive is the same within the European Union, the history of the legal systems in the different Member States shows that LUP can be implemented in several ways, using a deterministic approach, a probabilistic approach or tables of appropriate distances (Christou and Porter, 1999).

1.2 Risk management policy

To apply the Seveso II directive requirements and to develop a system on the control of major-accident hazards involving dangerous substances, the Member States need to built a risk management policy combining several tools.
To describe the risk management policy implemented in France, it is proposed to use the accident model constituted by the system :

- hazardous source : it is constituted by the hazardous installations, products, equipment, processes,
- flux of hazard : it is constituted by the dangerous phenomenon like dispersion, fire or explosion,
- receptors : they are the elements located in the vicinity of the hazardous installation that could be affected by the flux of hazard.

This model is presented in Figure 1.

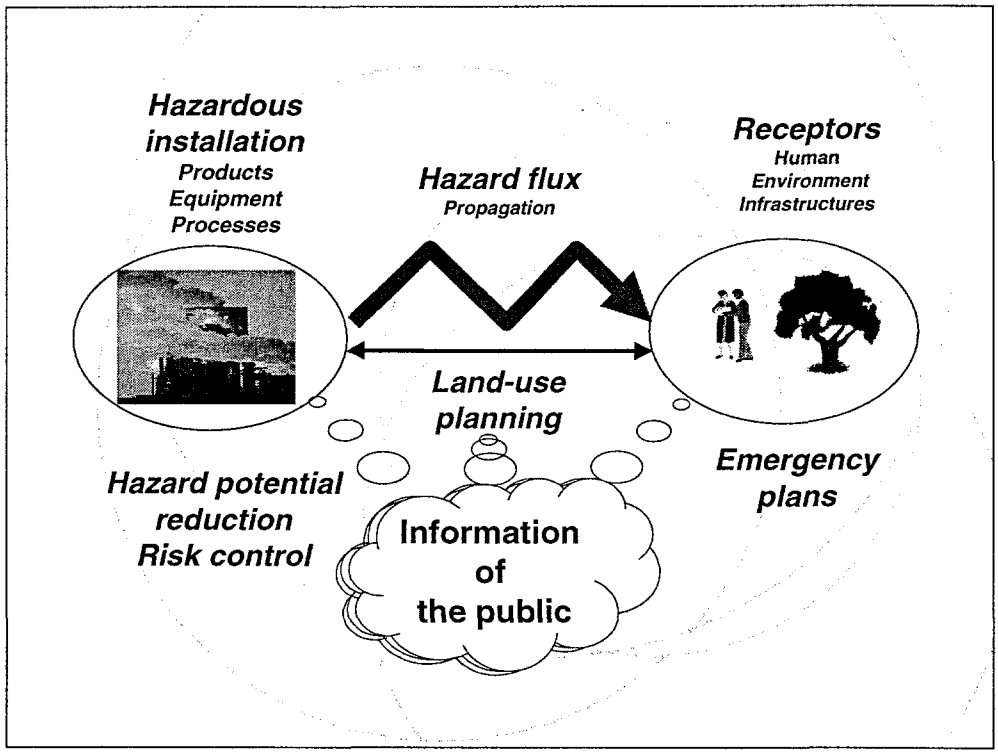

Figure 1 : Risk management policy in France

The Figure 1 presents also the four components of the risk management policy :

- risk reduction on-site : to reduce the hazard potential (amount of hazardous substances, process pressures and temperature...) and to implement risk control measures during plant operation,
- land-use planning : to maintain appropriate distances between the hazardous installation and the sensitive receptors,

- emergency plans : to prepare the public and the rescue services to behave efficiently in case of a major accident,
- information to the public : to inform the public about the possible consequences of a major accident and the behaviour they need to have in such a situation, but also to explain about the risk reduction on-site and the land-use planning objectives.

Using the model of Figure 1, it is clear that LUP is a complementary tool to the risk reduction on-site and to the emergency plans.
The philosophy behind LUP is to maintain a distance between the hazardous source and the receptors in case of a major accident, in particular if the accident can occur so quickly that the emergencies plans cannot be activated, or so that the number of people to evacuate is too high.
Another important issue is to be aware that LUP do not replace the risk reduction on-site, neither the emergency plans : all these tools are complementary. Moreover, LUP should not be applied before the hazard reduction phase, which is the start of any risk management procedure.

1.3 LUP : a decision making process based on risk assessment

As described in the Draft ISO Guide 73 (2001) on risk management, it is fundamental to distinguish the risk assessment process and the decision making process.
The guide explains that risk assessment is a part of the risk management process, ended up with the decision making.
Risk assessment is a tool used to measure the risk, characterised by the likelihood and severity of specific events.
Risk based decision making process is naturally based on the risk assessment criteria, but must integrate also other criteria that can be cultural, economical, ethical...
The decisions related to risk management have to be made for the interest of the Civil Society. The main goal of risk based decision making is to protect people and the environment.
Land-use planning is naturally a decision making process based on risk assessment. Having said that, the recommendations of the ISO Guide 73 should apply to the LUP procedure.

2 Current situation in France

The risk acceptance of hazardous establishments is a very complex decision process based on several criteria difficult to evaluate. In France, the only explicit criteria are those related to the consequences of accidents that are used to define the safety distances around hazardous establishments. They are linked to the LUP process.
This chapter present some key elements of the history of legal system and the current situation in France.

2.1 Obligation to keep the population away from the hazards

In fact, in the Code related to the control of hazardous establishments, the deliverance of the license to operate can be subordinated to a sufficient distance between the establishment and people located around (Code de l'Environnement, Livre V, Art. L512). In other words, the regulatory bodies can not theoretically license new establishments that can potentially harm

people in case of a major accident. This requirement is easier to apply for new installations than for existing ones.
This idea appeared first in an imperial act in 1810, then in a law dated 1917 on hazardous and unsanitary plants, but it was clearly reinforced with the law n°76-633 dated 19/07/1976 that was integrated in the 'Environment Code' on 18th September 2000.

2.2 Development of the French deterministic approach for risk assessment

To enhance a harmonised implementation of the philosophy of the law presented above, the French Ministry of Environment published in 1990 a guide (Secretary of State to the Prime Minister for the Environment and the Prevention of major technological and natural risks, 1990) that defined reference accident scenarios to be considered for determination of safety distances for land-use planning.
Then, in a circular letter published in June 1992, it was explained that the safety distances should be determined using the safety reports written for the licensing procedure. Consequently, to write the safety reports that aim is characterising the hazard of their plants, the operators have been asked to focus on the examination of the reference scenarios described in the guide. This approach is known as the consequence-based approach or as the French deterministic approach.
The term deterministic means that the assessed scenarios are pre-defined (See Table 1). They are considered independently of their likelihood, which is not assessed. The underlying philosophy is based on the idea that if sufficient measures exist to protect the population from the worst accidents, sufficient protection will also be available for any less serious incident.

Table 1 : Reference accident scenarios to be considered for land-use planning purposes

Type of risks and facilities	Type of accident scenario
Risks linked to liquefied combustible gas facilities (fixed, semi-mobile or mobile)	**Scenario A :** . BLEVE (Boiling Liquid Expanding Vapor Explosion) **Scenario B :** . VCE (Vapour Cloud Explosion)
Risks linked to vessels containing liquified or non-liquified toxic gases where the containment is not designed to resist external damage or internal reactions of products	**Scenario C :** . Total instantaneous loss of containment
Risks linked to vessels containing toxic gases where the containment is designed to resist external damage or internal reactions of products	**Scenario D :** . Instantaneous rupture of the largest pipeline leading to the highest mass flow

Type of risks and facilities	Type of accident scenario
Risks linked to large vessels containing flammable liquids	**Scenario E :** . Fire in the largest tank . Explosion of the gas phase for fixed roof tanks . Fireball and projection of burning product due to boil-over
Risks linked to use or storage of explosives	**Scenario F :** . Explosion of the largest mass of explosive present or explosion due to a reaction

2.3 Criteria for the evaluation of the consequences of reference scenarios

The criteria used to characterise the hazards are expressed only in terms of effect thresholds. They are used to evaluate the safety distances around the establishments:

- the distance at which the first death occur corresponding to probability of 1% fatality,
- the distance at which irreversible health effects occur.

The effects that are calculated with mathematical models are different according to the physical phenomenon involved in the accident scenario. The effect thresholds correspond to the phenomenon. A list of the thresholds is given in Table 2.

Table 2 : Thresholds for the evaluation of the consequences of the reference accident scenarios

Effects studied	Criteria corresponding to first deaths	Criteria corresponding to first irreversible effects
Thermal radiation	5 kW/m^2 (if the exposure is more than 1 min) or heat load of $1000^{(*)}$ $(kW/m^2)^{4/3}$ .s in case of a short exposure duration	3 kW/m^2 (if the exposure is more than 1 min) or heat load of $600^{(*)}$ $(kW/m^2)^{4/3}$ .s in case of a short exposure duration
Overpressure	140 mbar	50 mbar
Toxic dose	Based on $LC_1\%$ and exposure time (passage of the cloud)	Based on irreversible effects (first injuries) and exposure time (passage of the cloud)

(*) : these values are commonly used, but still under discussion

It can be noticed that, in case of fragment projection after an explosion, the maximal distance is evaluated but it is often not taken into account for the determination of the safety distance. Harmonised thresholds help to a coherent evaluation of the reference scenario consequences at a national level. Therefore, the French Ministry for Environment has published in 1998 a list of the most frequently used toxic substances (Service de l'Environnement Industriel, 1998). In this list, thresholds corresponding to the first irreversible effects are given. The

ongoing work on the determination of the toxic threshold are periodically published on http://www.ineris.fr.

The guidance for the selection of the reference scenarios and the explicit definition of the criteria to evaluate the consequences has contribute to have a consistent procedure, but at the moment we can still notice some discrepancies in the results for two similar installations.
Indeed a lot of parameters not defined in the guide have a great influence on the evaluation of the reference scenario consequences, in particular for toxic substances.
For example, some parameters should be more precisely defined in the guidance :

- The location of the line rupture or leak as a function of the pipe schedule,
- The duration of the leak according to safety loop with quick-cut valves,
- The duration of the exposure for long leakage, regarding possible response time for people evacuation or confinement,
- Meteorological conditions.

Moreover, we can still notice some discrepancies related to the models used for the consequence calculation and the assumptions made by the risk analysts.

3 How to improve the situation

Aware of the difficulties to implement land-use planning based on the risk assessment carried out for the safety report, the French Competent Authorities in charge of the Seveso II directive have launched a work on this topic in 2000.
INERIS has taken part in this work, on one hand, throughout a project entitled "Risk analysis and major accident prevention", and on the other hand, throughout the critical analyses of the safety reports asked by the authorities[2].
Thanks to this work, lessons have been learnt about the implementation of LUP and the risk assessment used for the LUP purposes. They are presented hereafter as guiding principles that could be used to improve the LUP procedure in France. However, some of them are so general, that they could be applied in other Member States of the European Union.
The views expressed in this paper are entirely the authors. They were partly presented in the report written for the mission of the General Inspectorate of the Environment after the Toulouse accident last year (Barthélémy et al. 2001, see annex T in tome IIb).

3.1 Distinguish risk assessment for giving the permit to operate and for LUP

In the safety report required by the Seveso II directive, the risk assessment should enable the operator to conduct a deep analysis on the hazards of a plant and the way to control the associated risks. The analysis should start with a systematic hazard identification and a risk analysis. Then, after the assessment of a set of scenarios, the adequacy of the risk control measures should be discussed. This requires the identification of worst case scenarios and of scenarios that take into account the safety barriers implemented by the operator. The comparison of these two types of scenarios shows the risk reduction and the gain provided by the safety control system.
In other words, the demonstration required by article 9 of the Seveso II directive, in particular that "major-accident hazards have been identified and that the necessary measures have been

[2] The French legal system allows the Authorities to ask a third party expert to make a critical analysis of a safety report provided by an operator of a Seveso plant. The critical analysis is paid by the operator and is delivered to both him and the Authorities.

taken to prevent such accidents and to limit their consequences for man and the environment" need a detailed risk assessment.
Based on this risk assessment, the authority can verify that the operator has "taken all measures necessary to prevent major accidents and to limit their consequences for man and the environment", as required by the Article 5 of the Seveso II directive.

The purpose of LUP is, as explain in Article 12 of the directive to "maintain appropriate distances between establishments [...] and residential areas, areas of public use and areas of particular natural sensitivity or interest". This objective can be interpreted as the need to estimate the consequences of major accidents in order to determine the zones in which the number of people should be minimized.
Having in mind this objective, it is proposed to estimate the consequences of accidents to define the zoning around hazardous establishments. This approach allows to reason on the hazard potential and not on the risk (combination of the severity and probability of the accidents).
It is important for 2 reasons :

- risk control measures can fail, then it is useful to know to what extend damages can occurred in case of an accident,
- there is less uncertainty in consequence assessment than in risk assessment.

To assess the consequences of accidents, scenarios must be defined. Since an accident scenario is the combination and the conjunction of several events, the assumptions related to the conditions of occurrence of the events including the functioning or not of some safety devices have a great importance on the final results.

3.2 Scenarios taking into account safety barriers

The scenarios that can lead to the most serious consequences are usually used to determine the emergency plans.
The scenarios considering that the safety barriers in place can prevent the occurrence of some events or reduce their consequences can also be identified. They are usually used to judge the adequacy of the safety control system which includes naturally the safety equipment and operations, and the organisational measures, both defined and animated by the safety management system.
For land-use planning purpose, intermediate scenarios are needed. Such scenarios should take into account some safety barriers, for example, those prescribed by standards and regulations. In particular, the safety barriers that are the most reliable should be considered.
These safety barriers should be identified, reviewed and consensually accepted by the authorities and the other stakeholders of the LUP process.

3.3 Defining certain assumptions related to the consequence assessment of the scenarios

In France, considering several risk assessments of similar hazardous installations, strong discrepancies appear on the estimation of the distances related to the apparition of the lethal effects and first injuries. This statement was the same in the ASSURANCE project (Lauridsen et al., 2001 ; Makert et al., 2001). This benchmark exercise allows to measure the size of the uncertainties in risk assessment and to propose some explanations. The results indicate discrepancies of about 4 orders of magnitude (variation of $1.5\ 10^{-7}$ to $2.1\ 10^{-3}$) in the probability estimation of some events. There is a factor 6 for the estimation of the consequences of a liquefied ammonia release in unfavourable atmospheric conditions

(variation from 1510 m to 9700 m for first injuries, and from 570 m to 3800 m for the first deaths).
These results are due to the great variety of possible assumptions related to the parameters describing the conditions of occurrence of the scenarios and the hazardous phenomena. The choice of these assumptions generates uncertainties on the estimated safety distances.

However, the decision making process constituted by the LUP should be homogeneous and consistent at the national level, and further at the European level.
Therefore, defining certain assumptions could reduce the discrepancy in the decision process, and should make it more transparent.
It is no more tolerable that the results depends on the experience, the feeling of a risk evaluator, neither the pressures related to the implication of the results of its estimations.
It is essential that the rules are the same for all, should they be discussed and determined after a debate involving all stakeholders : industry, authorities, mayors, communities and risk appraisers.
In order to make it explicit that the scenarios used to estimate the danger zones in LUP are based on predefined assumptions, it is proposed to call them *conventional or consensual scenarios*.

3.4 LUP, local concerns

LUP is implemented at the local level and should take account of local specificity.
The LUPACS project (Duijm, 2001) proposed a methodology for land-use planning involving chemical sites for making decision in local and regional administration. This European project expressed that LUP is a complex process involving actors at different decision making levels with different interests.
In that context, the estimation of the consequences of the proposed consensual scenarios should be one of the criteria used to define the danger zones for the use of land. But the problem has other dimensions than the risk level, and decision makers should take into account the social, economical, cultural dimensions of the problem.
The danger zones based on the consensual scenarios enable to identify the residential areas and other sensitive areas or infrastructures capable to be affected by the accident. They identify also the stakeholders who should be involved in the discussions and negotitation that will lead to find a consensus on the most adequate alternatives between :

- keep large zones around the plant and disable the development of the city;
- reduce the zones by implementing technical measures to enable the development of the city.

Both for new installations or existing ones, the danger zones should not be directly transposed. The implication of land-use by taking into account the hazard potential of a plant should be discussed at the local level, and should be analysed regarding all the aspects of the decision.

3.5 Suggestion of a 2 steps approach

Using the lessons learnt for more than 10 years, INERIS promotes a two-step approach that allows :

- To assess the hazard and estimate the danger zones in a homogeneous manner, following a commun procedure ;
- To develop and assess alternatives that can be negotiated at the local level, according to criteria that should be made explicit.

This approach is presented in Figure 2.

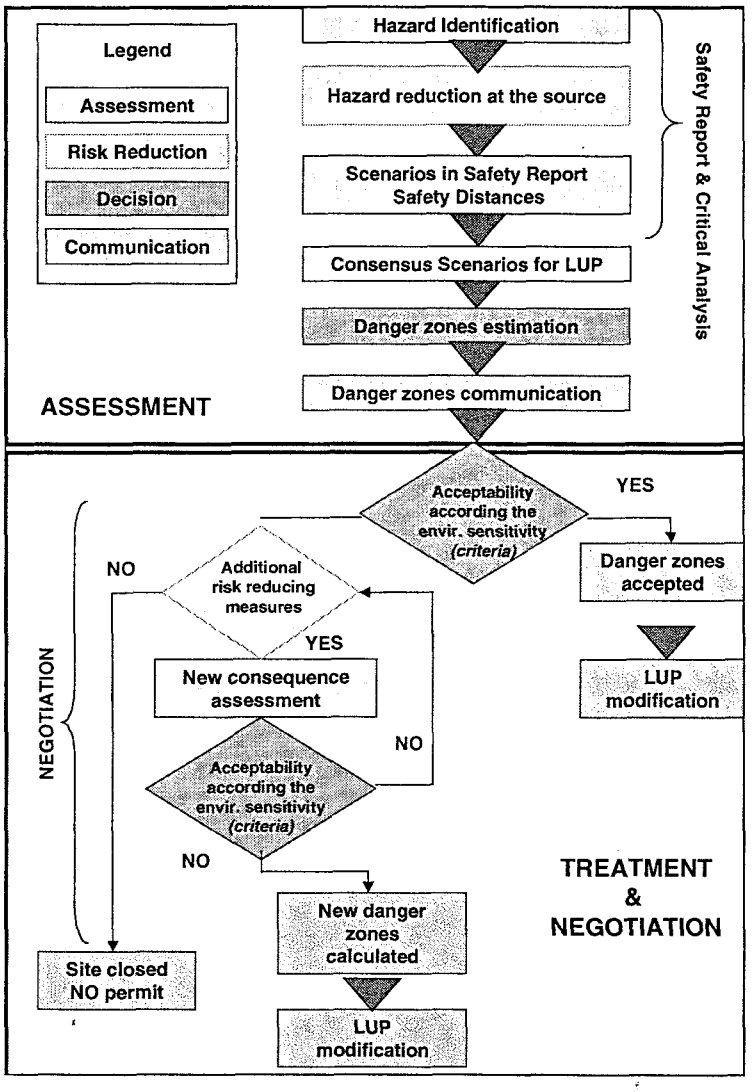

Figure 2 : Two-step approach for land-use planning

The first part of the approach is the risk assessment that leads to the estimation of the danger zones and their communication to the public, in order the public and the stakeholders know about the extension of the damages in case of a severe accident. This step is based on the examination of a set of scenarios in the safety report, covering the different hazardous phenomenon associated to accidents involving toxic, explosive and flammable substances. The consensus scenarios used to determine the danger zones should be defined in a guide, which is currently under development.

The second part is the treatment of the risk and the negotiation of the alternatives for the land-use planning, according to the local constraints like the composition of the environment in the vicinity of the hazardous installations, and socio-economical context. At this second stage, the discussions and the negotiation should associate the various stakeholders identified within the danger zones determined in the first stage. This phase of the procedure can be iterative if the local constraints need the implementation of several risk reducing measures to reduce the zones. However, attention should be paid in order to avoid that the final danger zones become too small, because then the principles of LUP (maintain a appropriate distance between the hazardous installations and the receptors in case of a major accident) would not be respected.

This two-step approach bring consistency in the hazard assessment, and transparency in the negotiation so as flexibility to take into account the local context.

Conclusion

As written in 1999, in the European Environment Agency report, major accidents continue to occur despite of the efforts of the industry and of the authorities. "Zero risk doesn't exist" is a reality.
This motto should reinforce the conviction that all stakeholders, in particular, the industry, the authorities and also the civil society should optimise the control of the risk in a best way, as a function of the resources of each, and of the benefits associated to the industrial activity.

It is also important to underline that the choice of accident scenarios for LUP purposes doesn't mean that a more catastrophic accident will not happen. The choice of scenarios and the estimation of their consequences is a tool to make a political decision.

The two-step approach described in this paper results from the experience of more than 10 years of application of LUP in France. It is based on an assessment of the consequences of accident scenarios and on transparent negotiation of the risk reducing measures to determine the final danger zones that are inscribed on the urbanism documents.

This suggested approach brings some elements of response to the European Council that expressed, at its Barcelona[3] meeting, the invitation " to develop a strategic approach on the management of technological risks, while considering the social, economic and environmental challenges in relation with the issue of sustainable urban development."

ACKNOWLEDGEMENT

This paper was partly supported by the project mentioned in the text that is funded by the French Environment Ministry.

REFERENCES

European Commission (2002), Report on the application in the Member States of Directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities for the period 1997-1999 (2002/C 28/01)

[3] See: "Presidency Conclusions - Barcelona European Council, 15 and 16 March 2002", p. 38.

European Environment Agency (1999). Environment in the European Union at the turn of the century, Chapter 3.8 Copenhagen, Denmark.

Secretary of State to the Prime Minister for the Environment and the Prevention of major technological and natural risks (1990), *Control of Urban Development around High-Risk Industrial Sites.*

Christou, M.D. & S. Porter (1999), *Guidance on land-use planning as required by the council directive 96/82/EC*, Joint Research Centre, European Commission, EUR 18695 EN.

Salvi O. and Gaston D. (1999), *Why changing the way to measure the risk ?,* Proceedings 9th Annual Conference Risk Analysis : Facing the New Millennium Rotterdam, 10-13 October 1999, The Netherlands. Edited by L.H.J. Goossens. Delft University Press, 1999 (pp 263-267).

Markert F., M. Christou, D. Hourtolou, and Z. Nivolianitou, (2001), *A benchmark exercise on risk analysis of chemical installations*, ESMG, Nuremberg March 2001.

Kirchsteiger C., G. Cojazzi (2000), *Promotion of Technical Harmonisation on Risk-Based Decision-Making, Workshop Proceedings*, JRC, S.P.I.00.63, Ispra, 2000.

Lauridsen K. et al (2001), Uncertainties in risk analysis of chemical establishments – the ASSURANCE project – 1998-2001. In Proceedings of the Seminar on Progress in European Research on Major Accident Hazards, October 10, 2001. Antwerp, Belgium. Federal Ministry of Employment and Labour.

Duijm N. J. (2001), Land Use Planning And Chemical Sites – the LUPACS project – 1996-2000. In Proceedings of the Seminar on Progress in European Research on Major Accident Hazards, October 10, 2001. Antwerp, Belgium. Federal Ministry of Employment and Labour.

Service de l'Environnement Industriel (1998), Fiches techniques - Courbes de toxicité aiguë par inhalation. Juin 1998.

Draft ISO Guide 73 : 2001, *Risk Management – Vocabulary – Guidelines for use in standards.*

Barthélémy François, H. Hornus, J. Roussot, J-P. Huffschmitt, J-F. Raffoux (2001), *Usine de la société Grande Paroisse à Toulouse - Accident du 21 septembre 2001, Rapport de l'Inspection Générale de l'Environnement.* Affaire n°IGE/01/034. Ministère de l'Aménagement du Territoire et de l'Environnement.