Major accidents scenarios used for LUP and off-site emergency planning : importance of kinetic description

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Abstract

The European States, France in particular, faced with several industrial accidents, like one of the most serious one, the AZF explosion in Toulouse (France) in 2001, which created the trauma of the stakeholders concerned by the chemical risk, (industry, authorities and citizen). Learning from this experience, the French Ministry in charge of the Environment, with the help of INERIS, worked on upgrading its chemical risks knowledge and studied to improve new methods on risk assessment. In 2004, INERIS was in charge of developing a new approach to classify accidental scenarios in terms of probability, severity and response time. In this paper, INERIS proposes a prioritisation based on time of occurrence, of development of hazardous phenomena and of effects on targets. Then, INERIS shows a method enabling to integrate, as a second prioritisation criteria, the on-site and off-site response capabilities/abilities as well as the means for population protection in terms of time allowed.

Keywords : Land Use Planning ; off-site emergency planning ; chemical accident scenario ; kinetic

1. Background

The European States, France in particular, faced with several industrial accidents of various causes and extent. The consequences of technological or chemical disasters such as those in Flixborough in 1971, or Seveso in 1976 (numerous casualties, major damage to the environment...), made international authorities to examine these phenomena and have especially led the European Commission to adopt legislation to prevent such events.

Two consecutive Directives in 1982[2] then in 1996 [3] gave guidance to member States to develop a prevention policy for major technological risks.

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[1] Institut National de l'Environnement Industriel et des Risques
[2] Council Directive 82/501/EEC of 24 June 1982 on major accident hazards of some industrial activities (Seveso I)
[3] Council Directive 96/82 of 9 December 1996 (Seveso II)on the controlling of dangers connected with major accidents involving dangerous substances (modified in December 2003)

The latter Directive was transposed to French law in May 2000: the upgrading of those installations with possible major technological risks is still being continued today.

In France, the AZF accident in Toulouse, on 21 September 2001, was truly traumatic for all stakeholders concerned by chemical risk, from industries operating chemical plants to administrative decision-makers, not forgetting interest groups and the citizen.

With reference to these research, and under the scope of the Seveso II Directive, the French Ministry of the Environment[4] (MEDD) set the 2003 act of Law [5] on Risks concerning Technological Risk Prevention Plan (PPRT).

INERIS is the technical support for the MEDD and offers expertise to Industries. INERIS is the reference body for risk analysis, determination of means to prevent major technological risks (chemical risks) and associated means of protection for SEVESO Installations and other fixed installations. INERIS also supports for authorities and industry for transportation of hazardous substances via pipelines, road, rail, inland waters, tunnels and port areas.

These facilities are consequently covered in safety reports. They are used to devise internal and external emergency plans and for prioritising emergency equipment in the preparation of crisis situations subsequent to chemical accidents.

In 2004, INERIS was in charge of developing a new approach to classify accidental scenarios in terms of probability, severity and response time.

About response time, INERIS proposed a first prioritisation based on time of occurrence, of development of hazardous phenomena and of effects on targets. As a second prioritisation criteria, INERIS showed a method enabling to integrate, the on-site and off-site response capabilities/abilities as well as the means for population protection in terms of time allowed.

This approach is compatible with the Methodology for the Identification of Major Accident Hazards (MIMAH) developed in the ARAMIS Project[6].

This paper reviews scenario characteristic used to establish Land Use Planning (LUP) and off-site emergency plans. Then it identify the difficulties encountered to co-ordinate LUP and emergency planning. An example of an off-site emergency plan integrating response time will be presented in the seminar.

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[4] Ministère de l'Ecologie et du Développement Durable - MEDD (*Ministry of Ecology and sustainable development)*

[5] Law n°2003-699 (2003, July the 30th) on natural & technological risk prevention

[6] Accidental Risk Assessment Methodology for Industries - http://aramis.jrc.it/

2. Definition and conventional analysis of accident scenario kinetic

The kinetic is one of the key elements necessary for classifying the scenarios of accidents those will be used especially for :

- a **LUP** establishment ;
- a Emergency Plans Elaboration.

As a preliminary, we would differentiate the notions of "time" and "duration", insofar as certain phases can be concomitant (the phases are thus not strictly successive).

Accident scenario kinetic is characterised by a **pre-accidental** phase and a post-accidental phase. The latter is determined by the dangerous phenomenon dynamics and the exposure of the targets (public, environment).

The **pre-accidental** kinetic study, duration necessary to lead to the **Critical Event (lost of containment)** which corresponds to the time between the **Initiating Event** and the release of the potential of hazard is not study in this paper but is integrated in the Safety Report. We would focus on the characteristics of the post-accidental **kinetic**.

On the one hand, it is necessary to distinguish the kinetic from the phenomenon and, on the other hand, the kinetic from the exposure of the targets. Insofar as the occurrence of the effect on the targets can, according to **cases**', being former (for example for a **fire** of warehouse) or posterior (for example, for a dispersion of a toxic substance following a ruin) at the end of the development of the phenomenon. These four kinetics are thus not necessarily successive.

Hazard phenomenon kinetic is characterised by :

- a Occurrence Delay **(d_1)** which corresponds for example to the time needed to the formation of one inflammable cloud in the case of a VCE
- ❒ The phenomenon development until its stationary state **(d_2)** : for example with the development of the fire generalised in the case of a **fire** of warehouse ;

With regard to the targets, the elements of kinetics are as follows :

- ❒ A time **(d_3)** necessary to the first physical effect on the target (toxic cloud displacement delay to hit the target) ;
- ❒ The duration corresponding to the exposure of the targets (d4).

It is also significant to appreciate the capacity of intervention (mitigation measures, safety **services**...), which can influence the times previously quoted overall.

In order to improve the understanding the temporal decomposition which has been just made, we can study a representation in bow tie (which characterises the development of a scenario of accident) to carry out a conventional analysis of the kinetics of accident :

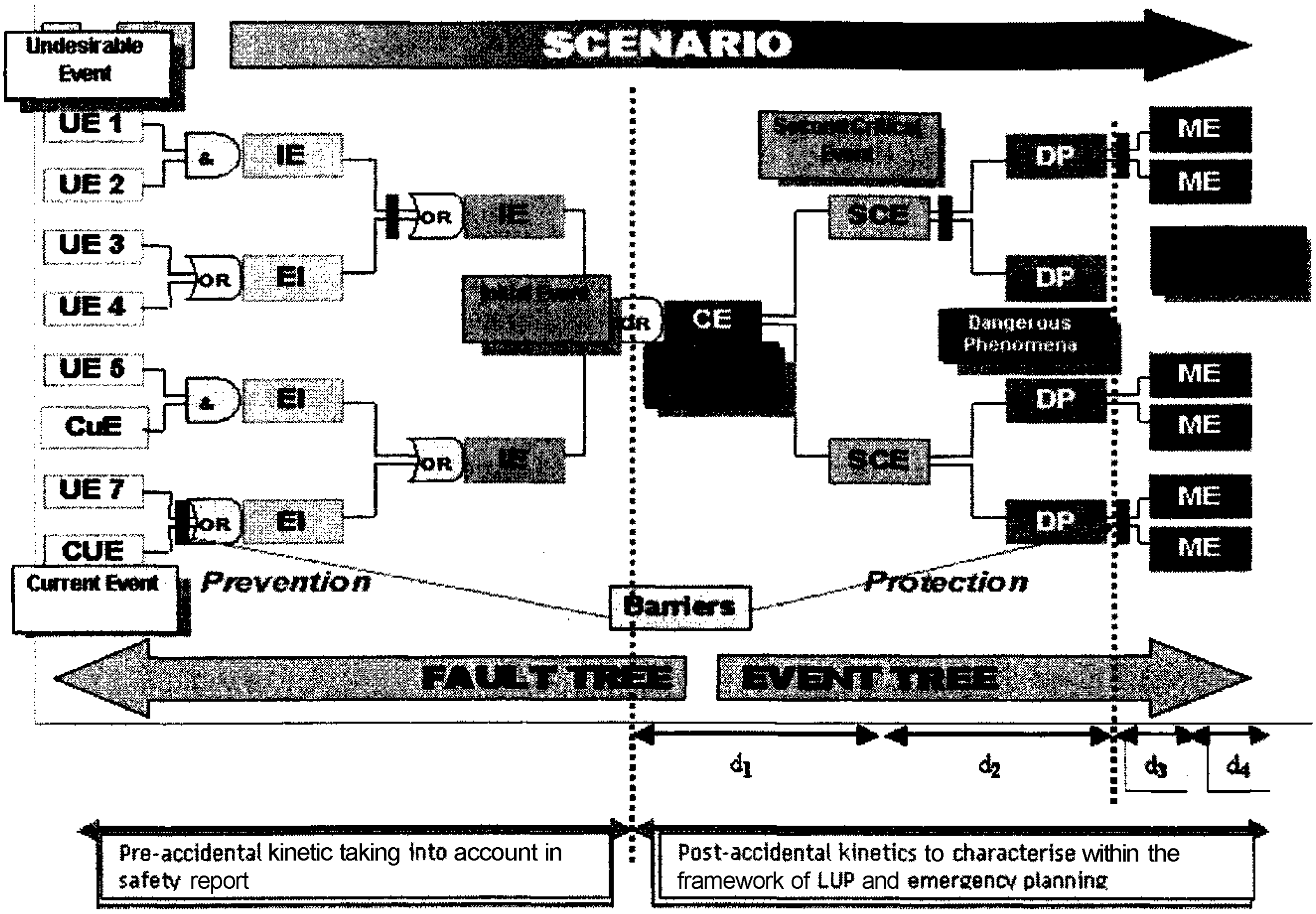

Figure 2-1 : Illustration of the kinetic on the bow tie

- This illustration is generic, and must be adapted to each phenomenon ; The illustration is not on the scale. The rise to power of the phenomenon could be extremely reduced ;
- The attack of the targets and the exposure could begin from the start of the phenomenon until its development. The attack of the targets (time necessary to the appearance of an effect on the targets) could be immediate.

3. Accident scenario prioritization

The following definitions will be used:

- Pre-accidental phase : former to the release of the potential of danger (between the initiating event and the release of the potential of danger) ;
- Post-accidental phase : posterior phase with the release of the potential of danger.

3.1 Scenario prioritisation to the pre-accidental kinetic

To illustrate this approach, the following table shows some various phenomena likely to occur on an industrial site and exposes, on the basis of lessons learned from past accident, the order of magnitude of associated times (in the order ascending of the duration).

Dangerous Phenomena	Initial Event	Pre-accidental duration
[redacted]		
Pool Fire	Loss of confinement	Immediate at several minutes (need an ignition source)
Jet Fire	Loss of confinement	Immediate at several minutes (need an ignition source)
Chemical substances decomposition	Contamination	Seconds (run away reaction) to hours (self sustaining NPK)
BLEVE	Thermal flux heating the vessel	Around 10 minutes - Depends on the chemical product, conditioning, fire power, vessel resistance, etc.
Boil-over	Vessel Fire	Hours

Table 3-1 : Pre-accidental kinetic of the various phenomena (e.g)

3.2 Scenario prioritisation to the post-accidental kinetic

The following table presents some various phenomena likely to occur on a factory site and exposes the order of magnitude of associated times with the development of the phenomenon, its duration, and the associated effects.

Dangerous pllenomena	d_1	d_2	Effects[7]
[redacted]			
BLEVE	Immediate : as vessel rupture	Several seconds (Fireball expansion & Fireball Combustion)	Th+P & M
Boil-over	Immediate : as soon as water evaporates	Several seconds (Fireball expansion & Fireball Combustion)	Th + Tox
Jet Fire	Immediate : as soon as product ignition	Several minutes to hours	Th + Tox
Toxic release	Immediate : as soon as leak	Several minutes to hours	Tox
Pool Fire	Immediate : as soon as product ignition	Several minutes to hours	Th + Tox
Warehouse Fire	Immediate : as soon as product ignition	Several minutes to hours	Th + Tox

Table 3-2 : Post-accidental kinetic of the various phenomena (e.g)

[7] **P - overPressure ; Th -Thermal ; Tox -Toxic ; M-Missile**

3.3 Duration to reach the targets

The following table presents the time necessary to the emergence of a physical effect on the target :

Overpressure	Immediate (propagation at the speed of sound)	Instantaneous
Thermal	Immediate (propagation at the speed of light)	Phenomena duration to hours
Toxic	Could be long (Depends of meteorological conditions and emission duration)	Could be long (depends of phenomena duration & chemical product characteristics)
Missile	Depends of explosion localisation	Instantaneous

Table 3-1 : Time length to exposure & exposure time length of various effects

3.4 First Conclusions

The phenomena could be characterised in several categories :

- « Very quick » phenomena : VCE & chemical decomposition ;
- « quick but delayed» phenomena : **BLEVE** ;
- « quick but very delayed» phenomena : BOIL-OVER ;
- long lasting phenomena but immediate effects : pool **fire,** jet fire, warehouse fire or confined fire, toxic release.

The case of chemical product decomposition is particular because the phenomena depends of chemical reaction conditions. It could be classified like a "very quick phenomena" or like a "quick but delayed phenomena".

4. Scenario prioritization taking into account safety services capabilities

The different delays for the safety services intervention could be decomposed in [2-3] :

O Alert : delay between the release of the potential of hazard and the event knowledge (type of phenomena and location) - a minima 10 minutes ;

© The movement of the Intervention Services on site : delay between the event knowledge and the effective arrival on the site - around 10 minutes ;

❸ The Intervention at different levels :

(a) To limit phenomena occurrence[8] ;

(b) And/or to limit its severity[1] ;

(c) And/or for the "*target extraction*" : (population confinement, evacuation) - a minima 15 minutes.

[8] These last two times are around **15** minutes for the installation of the means, time for which it is necessary to add the effective time of intervention. In addition, they get along only in the absence of victims which in, all the cases will be treated in priority

Three additional delays could be defined characterising the capacity of intervention of the public helps according to :

a d_5 : delay of the implementation of mitigation means before the phenomena occurrence ; it consists of (O + © + © a) and will be obligatorily higher than 45 minutes ;

a d_6 : delay of the implementation of mitigation means in order to limit the phenomenon severity ; it consists of (O + © + ©b) ; according to the availability of the means, it can be put in prospect in a field ranging between d2 and beyond d_5 ;

a d_7 : delay of the target extraction ; it consists of (O + © + ©c) and could begin as of the occurrence of the critical event (CE) and beyond d4 ;

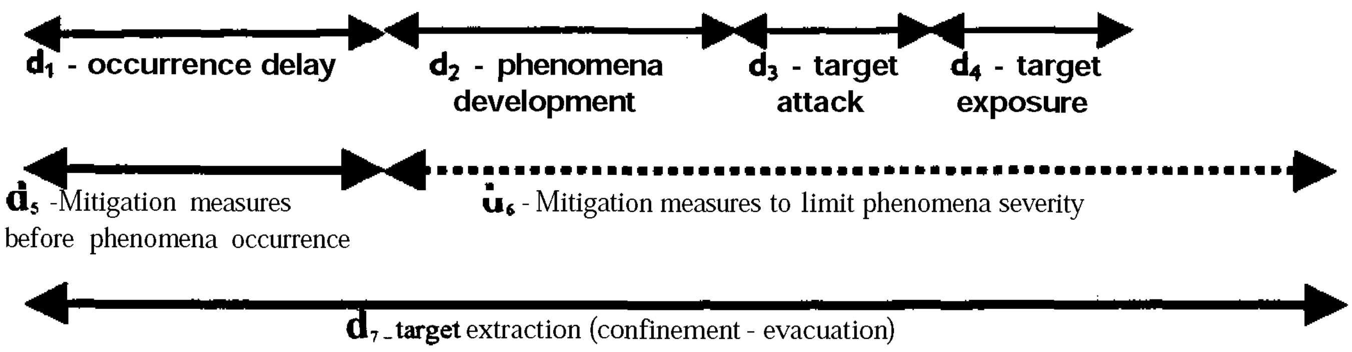

Figure 4-1 - Delay organisation

5. Propositions to characterize the kinetic taking into account safety practices

In comparison with these elements, INERIS proposed, with regard to the kinetic, the following approach :

a Each phenomena has to be characterised according to the delay d_1 to d4 (except the boil-over to which the pre-accidental dynamic will be considered) ;

a the justified choice of the delay d_5, according to the real capacity of local intervention is likely to "downgrade" several phenomena for a value of d1 higher than 45 minutes ;

a the justified choice of the delay d_6 is also likely to "downgrade" several phenomena in terms of severity ;

a the use of d_7 will make it possible to differentiate the selection from the scenarios to be used for LUP or emergency planning.

6. Conclusion

To conclude, the knowledge of the phenomena kinetic decomposition is useful to improve the definition of :

a The safety barriers as well as them dimensioning. These barriers can be technical or organisational and depending of the local context.

a The actions to decrease the targets vulnerability.

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