Development of a risk assessment methodology for seveso II establishments

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DEVELOPMENT OF A RISK ASSESSMENT METHODOLOGY FOR SEVESO II ESTABLISHMENTS

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ABSTRACT

In the aim to prevent and manage major accidents on an industrial site, many methodologies and directives have been developed. But, in France no formalised methodology has been proposed to competent authorities to determine a risk level of an industrial site. A first work of methodologies' synthesis permitted to propose some basis of a new methodology. This one will be based on the industrial site, the environment and the safety management. To reach this aim, four indexes are developed; the first one concerning the hazard source (the establishment), the second one the flux (the vector of propagation of accident considering the specific environment), the third one the vulnerability of targets (human, environmental or equipment), and finally the fourth one concerning the safety management (prevention and protection actions). This new approach will provide a cartography of risk level for an industrial site and its vicinity to bring a decision help for risk managers and competent authorities.

1 INTRODUCTION

The SEVESO II directive [1] aims at preventing major accident that can harm people and the environment around industrial establishment. In France, the Competent Authorities in charge of the application of the SEVESO II directive have no formalised methodology to assess the risk related to major accident. A consequence of the lack of a formalised methodology is that safety measures to prevent major accident are not always taken into account in a consistent manner for the determination of the safety zones.

And generally speaking, in France, the safety zones are determined on the basis of potential hazard, calculated without taking into account neither all safety devices nor the efficiency of the safety management [2]. In order to better understand the problem, we can take an example : two similar establishments, with the same products, the same process, and with equivalent quantities. The first establishment has a high level of safety, while the second implements only the strict minimum to face up major accidents. At the moment, considering only the potential of hazard, the safety zones associated to the two establishments could be at the best the same. Indeed, because of the lack of formalized method, it is impossible to compare in an unambiguous way the level of risk between two establishments.

The objectives of this study are to propose a risk assessment methodology allowing a first diagnosis by focusing on major accidents and by taking into account all the actions aiming at improving safety. This method brings out the efforts carried out by the operators to maintain the establishment at a high level of safety.

This paper presents the first development of the methodology.

2 STATE OF THE ART

Thanks to a bibliographical review of risk analysis methodologies, we identified and studied 62 of them. The analysis of these methodologies leads us to highlight some essential features of an operational method :

- Ranking criteria : the method should allow to rank the hazard and the other parameters that contribute to define a risk level, the sensitivity of the environment, the efficiency of the safety management.
- A global approach : the method should allow a global analysis and should be applicable for various industry types.
- Simplicity of use : the basis of the method should be clear and simple for two reasons :
  - To allow the dialogue between risk experts and the operators ;
  - To allow that the operator continue to use the method without the expert help.

Among these sixty-two methodologies, some positive points can be extracted in order to assess the risk level. The main points are :

- the industrial site (as in a classical approach)
- the distribution way of accident
- the exposure level of the environment
- the safety management

None of the methodologies has really taken into consideration all the four points above. Generally, whether methods are so general to provide an effective help decision or so specific to only a part of the studied site.

3 METHODOLOGY

This section describes the methodology which is being developed. It is based on the determination of 4 indexes to characterise the risk level of an industrial installation in its environment.

3.1 System schematisation

If we bring these considerations in the context of the SEVESO II directive, the following points can be added :

- Bringing out the safety measures organized in the safety management system against the major accidents [3],

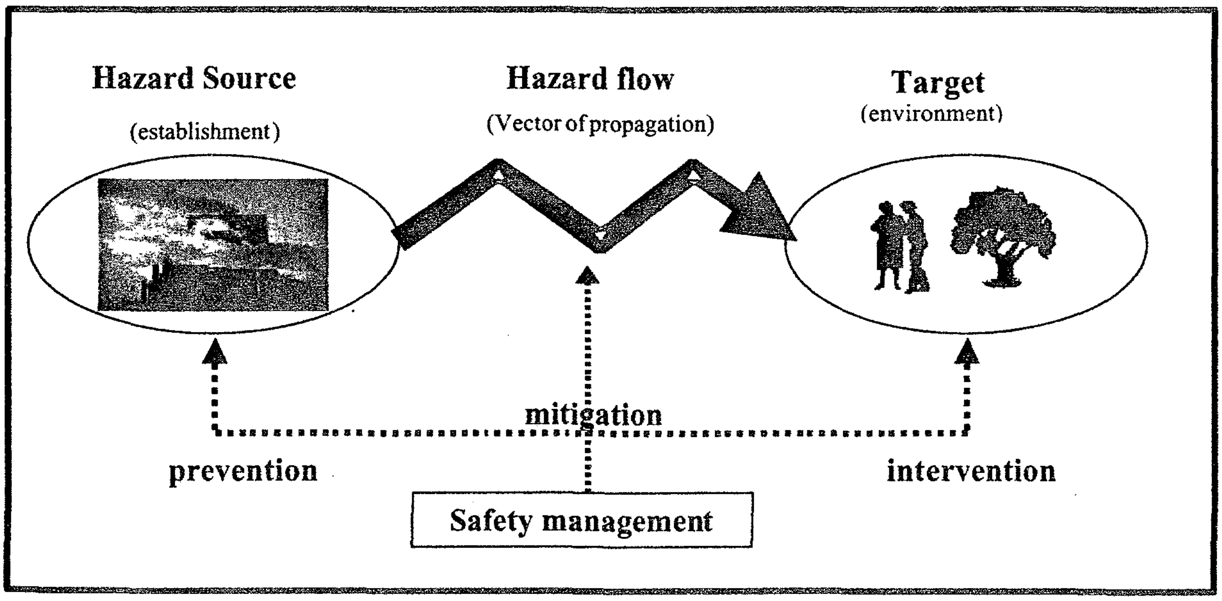
- The need of harmonization,
- The integration of domino effects [4].

Finally, we propose to build up a new methodology based on the following features :

- The use of risk index (ranking method) like Avrim2 method [5] or Risk Level Indicators method [6]
- The integration of the vulnerability of the Environment (human, environmental natural and material) [7] based on multi-criteria decision analysis with SAATY's method [8],
- The use of an analysis of the safety management system[5].

The figure 1 hereunder explains the functioning of the method.

Figure 1 : schematisation of the method



From the zone of study, one can extract four dominating elements :

- hazard source (the establishment)
- hazard flow (the vector of propagation)
- target, located in the vicinity of the establishment
- safety management, implemented by the operators.

Each of these elements allows to define four indexes, that after integration, constitute a function of risk level. Actually, the used data are mainly located in safety reports and their processing gives a risk level quantification. Finally this permits inspectors to assess the safety management level for the industrial site.

The method includes two main phases.

- The first phase consists in estimating :
  . The severity index S, considering the major accident hazards generated by the source.

- . The flow index F, characterising the vector of propagation with the notion of exposition level.
- . The vulnerability index V, characterising the environment including various targets types (human, natural environment, material) by means of methods of multi-criteria decision.

- The second phase characterizes the efficiency of safety management.
  - . The safety management index M takes into account the various types of barriers (technical and human operation) on the hazard source and the hazard flow, as well as the intervention capacity of the internal / external emergency services.
  - . The objective is to highlight actions led by operators to decrease the risks on their establishments.

3.2 Index definition

3.2.1 Hazard source : Severity index S

The industrial establishment is characterised by the severity index S. The potential hazard should allow to take into account and to quantify the level of risk of each critical area of the industrial establishment studied.

The study of the industrial site is based on a functional scheme of the site and on safety reports [9]. The first phase consist in identifying critical areas. A critical area is a part of the site which is likely to generate a major accident. For each critical area, an event tree is developed from initial events to the undesirable event leading to major accident [10].

To characterise major accident and the potential hazard, we must identify all parameters describing the accidental phenomena. The physical effects [11] generated by the source are overpressure, thermal flux, toxic gas dispersion, and liquid pollution.

Two type of major accident can be identified a sequence of events leading to one major accident only, or a sequence of events leading to more than one major accident (domino effect). Then two variables of potential hazards (PH) may be determined :

- direct PH,
- indirect PH or domino effect PH.

P H direct is function of Dangerous good used or stored and processes implies. It is very important to consider stored products and goods' flux.

Specific criteria for dangerous goods are quantities of product likely to be involved in a major accident and some chemical or physical characteristics in function of considered physical effect :

- overpressure : chemical features (Lower and Upper Explosion Limit...),
- thermal flux : chemical features (heat of combustion, emissivity...),
- toxic gas dispersion : toxic threshold, effect generated on health,
- liquid pollution : toxic threshold, effect generated on health or environment.

Specific criteria for processes are considered like aggravation factors. In function of conditions of process some penalties are attributed to the variable P H. A list of hazard process [10] is :

- A : System *source of hazard of mechanical origin*
- B : System source of hazard of chemical origin
- C : System source of hazard of electric origin
- D : System source of danger of fire development

The combining of process and dangerous goods parameters will provide the direct Potential Hazard. The indirect P H or the domino effect P H highlights major accidents implying domino effects and a correction factor is attributed to the direct PH in function of the severity of the final accident. The combining of PH direct and PH indirect will allow to calculate the Severity index of the source.

3.2.2 Propagation vector : Flow index F

The propagation vector will allow a description of the accident modes of transfer according to the physical environment of propagation to characterize the level of target exposure [12].

In function of considered physical effect, the mode of transfer increases or decreases the potential hazard of the major accident.

The propagation vector index F is function of the distances between targets and source of hazard, the environmental features, and the kinetics of accident propagation.

For example, to take into account :

- a toxic gas dispersion : a distribution of wind must be considered.
- a fire or explosion : it will be interesting to consider or not the presence of natural barriers.
- liquid pollution : it will be interesting to consider the propagation speed as a function of target distance.

3.2.3 Vulnerability : Vulnerability index V

To assess the vulnerability of targets in an industrial establishment, we must considered the accidental phenomena issued from the site and identified some criteria described the sensitivity of targets [7].

The notion of impact must be taken into account to characterize the sensibility of targets into environment. In fact, major accident leads to a physical effect that generated several types of impacts on targets. Four kinds of physical effect can be considered for characterising the sensitivity the overpressure, the thermal flux, the toxic gas dispersion, the liquid pollution.

All these physical effects induce impacts which can be ranked in three categories :

- sanitary/environmental/integrity impact,
- economic impact,
- psychological impact.

It is important to consider that impacts, generated by physical effects, have a direct influence on targets and that is not the physical effect itself. But the importance of impact depends on the considered physical effect. Indeed, for an overpressure the economic impact may be more important that for a toxic gas dispersion.

The sanitary/environmental/integrity impact provides information carried on the target sensitivity in front of physical effects concerning the functioning preservation of target. The economic impact provides a characterisation of the whole cost induced by major accident. The psychological impact characterises the human sensitivity from the effect on the different types of targets.

In this first part, only the physical effect and impact were being described and not targets. Targets correspond at human, environmental, or equipment targets which have a sensibility in front of major accident. It must be interesting to separate targets in three classes (human, environmental and equipment) in the aim to distinguish three values of vulnerability. Each class of targets will be described in five categories, in this manner the whole targets can be taking into account.

- Human class [13] is composed of the following categories :
  - industrial establishment worker,
  - rural and semi urban settlement (low and medium density of population),
  - urban settlement (strong density of population),
  - establishment public receiver (like passenger station, hopping centre, structure linked to spare-time activities, general knowledge, health services and public services),
  - large communication way (motorway, railway, road way with high density).
- Environmental class [13] is composed of the following categories :
  - agricultural activities with a high market value (market gardening, vineyard)
  - agricultural activities with medium market value (wheat, colza)
  - vegetation (forest, environment with herbaceous or bushing vegetation, zone without vegetation like beach)
  - specific natural site (conservation area, nature reserve, national and country park)
  - expanse of water (sea, swamp, lake, pond, river, water spring, aquaculture area).
- Equipment class [13] is composed of the following categories :
  - industrial establishment,
  - public structure (safety services, communication network, gas and electricity network, rail and road network, bridge, tunnel, airport),
  - equipment implied in drinking water (storage, treatment, distribution and harnessing equipment),
  - living quarter (house and building),
  - public building (administration, school, university, church, monument, museum, leisure equipment, market area).

A value of vulnerability will be calculated for the whole categories of targets in function of a physical effect and impact too.

The characterisation of the environment was being presented previously, but it is necessary to rank the sensitivity of target according to the major accident. To reach this aim, a multi-criteria analysis method is used : the SAATY's method [8]. This methodology is based on expert judgement which provides a rank of the sensitivity of each target sustaining an impact due to a physical effect.

To solve this problem, SAATY's method is used at 3 consecutive levels :

- 1st level : The determination of sensitivity of a target in front of each physical effect is realised.
- 2nd level : For each physical effect, the importance of impact is ranked in function of each type of targets.
- 3rd level : For a physical effect given and a type of target given too, the sensitivity of target categories is ranked in function of impacts.

The whole matrix calculation will give a value of vulnerability for each category of target sustaining an impact due to a given physical effect

For the application of the methodology, the studied area is cut into meshes. In each mesh, the first phase is to make a census of whole targets and so the determination of the vulnerability value of this mesh will be able.

The combination of severity and flow and vulnerability index characterises the potential hazard of the system.

In second part of the work that will be carried out, a Control/Management parameter will be establish to evaluate the global risk level.

3.2.4 Control/Management : Safety Management index M

The Control/Management parameter will allow to take into account the different types of technological barriers [10] (prevention, protection and intervention) and to assess the influence of the Safety Management System.

The combination of Potential Hazard of the system and the safety management index allow to calculate the level risk index.

4 CONCLUSION

The methodology proposed in this paper deal with the assessment of the risk level of an industrial establishment by taking into account safety devices and safety management.
Indeed, the first phase of the methodology, presented here, provides the characterisation of a potential hazard. The potential hazard allows to assess dangerousness of the site (process and dangerous goods) and to take into account, on the one hand, the propagation vector of major accident toward the environment and, on the other hand, the environment vulnerability.
The second phase will integrate all safety devices to modulate the potential hazard. The combination of the four parameters will provide a risk level to characterise the risk generated by an installation in its environment. The proposed methodology provides a global approach of the level risk determination. This application allows to assess the risk level and ways to decrease it and to highlight actions of prevention. This methodology should help decision-making to manage safety on industrial sites.

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