Knowledge management and major industrial hazards : an integrated approach

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Abstract

The reflection that followed the Toulouse 2001 accident has stressed the fact that there was an urgent need for a coherent and trustable information about industrial hazards. This is true for the public who needs to be informed about the surrounding risks but it is also, and all the more, true for the industrial operators who have the responsibility to assess the risk and take the necessary provisions to reduce it, the workers who face the risk everyday and the competent authorities, in charge of the control.

With this context in mind, INERIS is developing a series of tools for the knowledge management in the context of industrial major hazards. The aim is to make accessible the right information to the right person at the right moment. For this purpose, it is necessary to clearly analyze the needs of the different actors of industrial risks management and then to propose the structure of the system that will support and make the knowledge available.

This paper presents the results of this preliminary analysis. It describes the first features of the system developed in the framework of this project, PRIMARSIK®, and illustrates how it was built in a fully integrated approach of knowledge management. PRIMARISK® is not only a way to make different models and data available but it is also a way to provide the structure for future capitalization of the knowledge.

Key words: Knowledge management, industrial hazard, risk assessment.

1. Introduction : Situation in France after the AZF accident

The AZF accident that occurred in Toulouse in September 2001 has led to a large debate about risk management in and around industrial sites. Among the conclusions of this debate was the evidence that knowledge was not enough shared among stakeholders with a series of consequences. The report of the inquiry commission leaded by the deputies F. Loos and J.Y. Le Déaut [1] mentions a loss of memory resulting to an everyday acceptance of risk. The safety studies realised by plant operators or, more often by consulting firms were often of poor quality and could lead to very different results in comparable situations. The decisions were taken without a real debate among the stakeholders : plant operators, populations, local communities, state authorities. This lack of debate and of diffusion of the knowledge had the consequence of reducing or falsify the perception of the industrial risk by the population but also by local community representatives.

The Toulouse situation is not unique. In France, the proximity of urban zones (housings, commercial activity) with industrial zones is common due to the historical context. Initially build outside the cities, the plants were progressively circled by the houses in a time when the legislation was not sufficient and was not imposing land use restriction. The opposite also existed: plants newly build or, more often, modified to increase their capacity in the middle of an existing city. With time an evolution of the population also occurred. In the origin, the surrounding population was often composed of people working in the hazardous plants, thus having some knowledge of the industry and its dangers. Part of this population moved to more comfortable places away from the industrial zones, and were replaced by people having no link with the plant and no risk culture.

The legislation evolved but, in many circumstances, the local political or economic pressure as well as the poor understanding of the risk by the local representatives, the population and even sometimes the administration, led to the continuation of abusive growth of the suburbs around the hazardous plants.

2. Cindynics analysis of the situation

G.Y. Kervern has developed a conceptual model (Figure 1) for the investigation of hazardous situations generated by organisational deficiencies. This model states that a hazardous situation can always be analysed in terms of **values, rules, objectives, models** and **data [2]**. When the actors of the situation lack or experience differences in one of these elements the situation presents a risk. It is qualified **of *cindynogenic***.

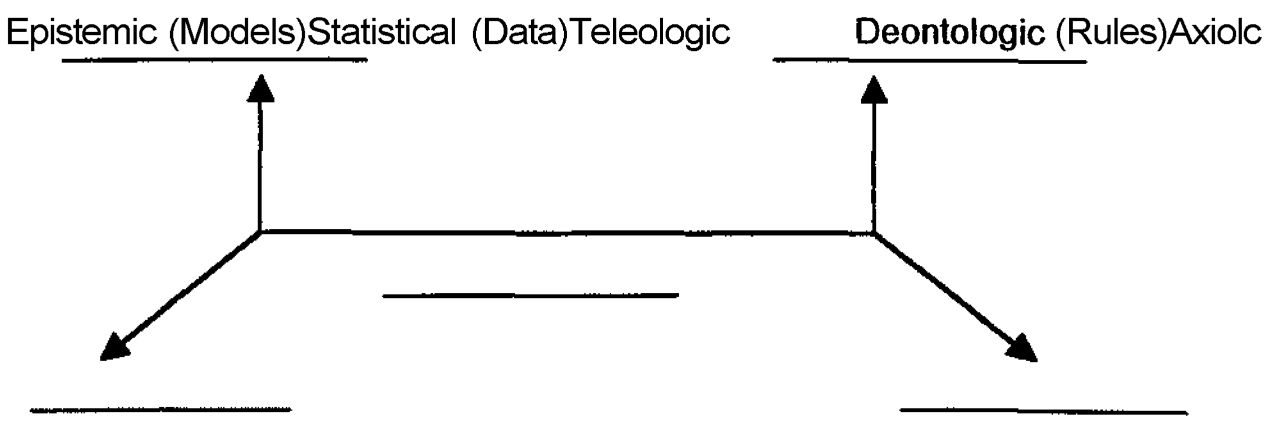

Figure 1 : The hazard hyper-space model (G.Y. Kervern) [2]

Using this model helps to understand the reasons of the AZF accident and its dramatic consequences. Indeed, differences **of values** and **objectives** existed between the industry, the population, the local and the national authorities. For example the population demanded more information and possibilities to express its opinion whereas the national authorities had the belief that the question was too complex to be debated and that the *elite of the republic* could certainly find the most rational and adequate solution. The industry and, somehow the local authorities were asking for less obstacles to the economic growth in the plant and around them.

To face these differences, the **rules** were insufficient. Their requirements were not clear enough, leading to divergences of interpretation. They were also not adapted to the situation of the many cities where an hazardous industry was cohabitating with a urban area.

The last deficiency concerned **models and data.** The report by F.Loos and J-Y.Le Déaut was underlying the necessity to improve the knowledge of hazardous substances and to improve the risk assessment methodologies [1]. It was also insisting on the very broad variety of results obtained by the risk analysis of industrial plants. The European project ASSURANCE [3] realised in the same period had shown that for a same set of data about the same plant, the results of the risk analysis could vary by a factor 5 in terms of distances of effect and by a factor 1000 in terms of probability. This project was involving the top consulting firms and national risk institutes of seven European countries. Part of these results could be attributed to the lack of knowledge, the imprecision of models and the assumptions made to compensate them.

From the previous paragraph it can be concluded that the situation in terms of hazardous risk managements was ***cindynogenic***. Progress had to be made for an improvement and sharing of common values, rules, objectives, models and data.

The values reflect what is considered as essential by the stakeholders. The values change slowly as the results of the general public debate and the evolution of the society. The debate that followed the accident contributed to the reinforcing of a common certitude that the management of risks around industrial sites could not be a solely technical activity and that, as the most concerned were the population, and the workers of the plant (who are often the same), they should be involved in a democratic way. A common value was that making profits could not justify to let risks uncontrolled. And, somehow, the question was too serious to be let in the sole hands of the technical experts and the politicians.

The rules are the results of the legislative and regulatory process. They are the formalisation and the implementation of the values. The debate that followed the accident in Toulouse led to the voting of a new law (n° 2003-699) of July 30th 2003 [4] relative to the prevention of technological and natural risks and the compensation of the damages.

The new law aims at reversing the effects of the past lack of knowledge or differences in rules and values by introducing new rules and reducing the vulnerability around industrial sites. The evolution of the legislation aims at reinforcing the democracy by introducing a debate before the taking of decisions. Somehow this debate should also reduce the divergence of objectives among the actors as it should bring the actors to formulate common objectives in terms of risk reduction and control.

But the debate between the stakeholders only can work if its actors share common models and data. Those are often the result of a scientific process. Their formalisation and making accessible to the stakeholders is a typical knowledge management task that will be described in the next paragraphs.

In fact, the objectives of making the knowledge available go beyond the need of facilitating the debate. It also aims at making the risk assessment more efficient by providing to the people in charge of this activity the necessary models and data. It also aims at facilitating the comparison and interpretation of the results by the stakeholders, and then, it enhances the transparency of the decision-making process.

3. What Knowledge management can bring

*Knowledge Management is the process through **which** organizations generate value from their intellectual and knowledge-based **assets**[1].* Knowledge management recovers all the methods and techniques that can be used to make the knowledge available and usable by those who pertain to the organisation.

The knowledge can be divided into two main categories : the explicit knowledge and the tacit knowledge.
The first one is the knowledge that can be documented, the second one is the knowledge that resides in the people's mind in a more or less formalised form. One of the aims of knowledge management is to transform the tacit knowledge into explicit knowledge. A second one is to make the explicit knowledge accessible to people who may benefit from it.

One of the first step of knowledge management can constitute in the formalisation of expertise : making the expert tacit knowledge become an explicit knowledge understandable by other people. This is what was done in **INERIS** with the writing of the Ω reports. These reports are a formalisation of the present knowledge of INERIS experts on various subjects related with the management of major hazards. The second step is to make this knowledge available to other potential users. This was done by the diffusion of the *Q* reports on the web site of INERIS. Table I lists the already available reference documents. The same number is under preparation at the moment.

Yet, this was not sufficient as the knowledge required to assess and control risk and to take decisions in a risk environment is not limited to literal knowledge.
The risk expert uses a large variety of models and data associated to the various steps of risk assessment processes. To make these models, tools and data available to the risk assessment community, INERIS is presently developing the resource platform **PRIMARISK®**. It should be available to the public in the course of year 2006. The next paragraphs describe the main features of this web platform and present its basic structure in relation with the needs of potential users.

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[1] http://www.cio.com/research/knowledge/edit/kmabcs.html

Table I : list of the Ω reference documents available on www.ineris.fr[2]

Ω-1	Guide for the conception and operation of farm-produce storage capacities with regard to the fire and explosion hazards
Ω-2	Pool fire
Ω-3	Lightning hazard in process plants
Ω-4	Modelling of a fire affecting aerosol generators
Ω-5	BLEVE - phenomenology and modelling of thermal effects
Ω-6	Important for safety elements
Ω-7	Risk analysis methods for industrial installations
Ω-8	Jet fire
Ω-9	Safety report of an industrial plant
Ω-10	Assessment of the performances of safety barriers

4. Structure of knowledge

The heart of the process leading to the decision making around industrial sites is the risk assessment process.
It is structured as follows:

- Hazard identification;
- Description of the scenarios;
- Determination of the dose-response relationship;
- Estimation of the risk emission;
- Estimation of the exposition to risk;
- Risk evaluation.

Each of these steps requires that some knowledge be mobilised to produce the expected results. Specialists of risk assessment, experts, implement this process for the benefit of the community and the decision makers, who need to have a good understanding of the process itself and of its different stages to be able to interpret properly its results.

It requires also from them an initial understanding of these basic concepts : hazard, risk, accident, severity, vulnerability, and of the general decision-making process based on risk analysis.

5. Specific risk assessment processes: the example of the safety report of industrial plants

Specific risk assessment processes are defined by the legislation, standards or state of the art. At the end of its development, PRIMARISK® will describe several risk assessment processes related to the main activity domains of INERIS. The first to be implemented in PRIMARISK® is the safety report of a hazardous industrial plant (in French : étude de dangers). It involves the following steps :

- Description of the plant;
- Identification of the hazardous pieces of equipment;

[2] These reports are prensently available only in French. The title was translated into english for the sake of the present paper.

- Selection of the pertinent equipment;
- Risk analysis;
- Identification of the safety barriers;
- Assessment of the consequences of accidents;
- Definition of the safety control and requirements for the safety management system.

Each of these steps mobilises a specific knowledge.

The description of the process is explicit but the understanding of which models, tools and data to use is more of a tacit type. The expertise lies in the ability to use the right model for a given hazardous situation. It lies also in the capacity to understand the results of the process.

Therefore, the first step of knowledge description involved the description of the risk assessment process. To ease the understanding, a logical decomposition was decided. The risk assessment process is composed of steps. Each step involves the fulfilment of tasks.

In PRIMARISK®, each steps is described in terms of objectives. The relevant legislative texts are given together with other reference text, when they exist. Then the tasks are listed. Each of them is described and linked with useful resources.

The resources can be of three main types :

- Local resources : PRIMARISK® lists the elements of information that the person in charge of the risk assessment has to obtain from the plant operator such as the maps or process instrumentation diagrams.
- General resources : these are the resources available elsewhere that the user should consults to obtain useful information. Most of these resources are available online from other web sites. Among these are databases, documentation etc.
- Specific resources available directly from **PRIMARISK®**: These are tools and databases that were developed specially for being made accessible through PRIMARISK®.

Figure 2 shows the general structure of PRIMARISK®. The core system was implemented on a database and establishes the link with classical web pages and more specific online software.

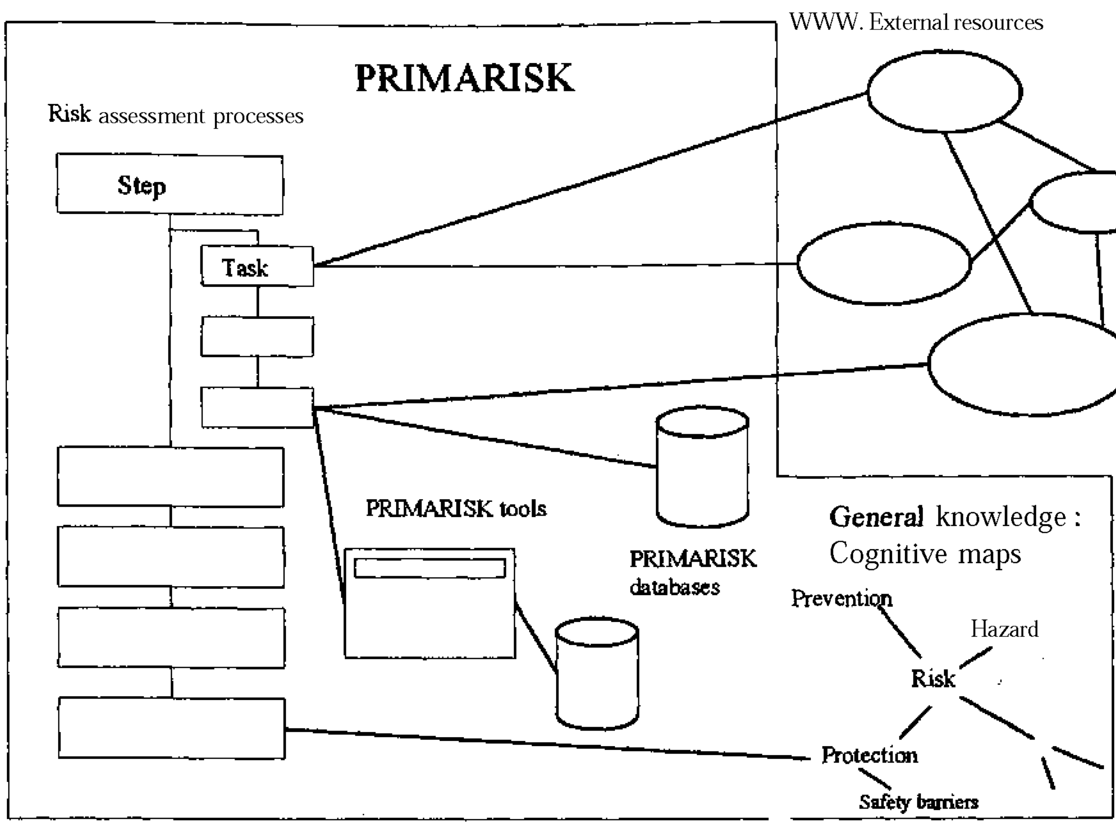

Figure 2 : general structure of PRIMARISK®

1.1. Risk analysis methods and support tools

Risk analysis is an essential step of the safety report elaboration. Depending on the type of activity considered, different risk analysis methods can be used. PRIMARISK® provides descriptions of some methods as well as support tools, check lists, tables etc.

A decision support tool for the choice of an appropriate method is also proposed. The selection involves the type of process to be analysed, the complexity of the method, the depth of the analysis or the integrated aspect of the analysis.

A second development step will lead to the building of a complete risk analysis support tool dedicated to the management of the data collected during risk analysis. This tool makes use of the bowtie representation of the accident scenarios, which was promoted by the European project ARAMIS [5].

The associated risk analysis process begins with the identification of the hazardous equipments in the plant. ARAMIS provides lists of hazardous equipments[3] together with the critical events they can provoke. For each critical event, the method also proposes a generic fault tree and event tree that serves as initial basis for the risk analysis. A database with the hazardous equipments, their descriptions, and the associated fault trees and event trees was build in PRIMARISK®. It can already serve as a support for risk analysis before the building of the future tool.

A next step involves the identification of safety functions and safety barriers. A database with typical safety barriers for different types of activities, BADORIS[4], was already developed in INERIS and is available online.

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[3] http://aramis.jrc.it
[4] http://badoris.ineris.fr

Once the safety barriers are identified, their efficiency is assessed so that finally the frequency of the accident scenario may be assessed. This step has revealed to be relatively difficult because of a general lack of data about initiating events or reliability of the safety barriers. Producing such data could be an objective assigned to a knowledge management tool such as PRIMARISK®. This goal will be discussed in paragraph 11.

1.2. Tools for the modelling of the consequences

The tools presently proposed in PRIMARISK® are mostly mathematical models for the assessment of the consequences of accidents. Most of them were developed as a result of INERIS research programs. They are dedicated to the modelling of physical phenomena such as fire, explosion or BLEVE (boiling liquid expanding vapour explosion). Progressively PRIMARISK® will provide a complete set of tools for the description of all the relevant phenomena that can be associated to major hazards.

Beyond, PRIMARISK® also aims at providing the expertise in the selection of the appropriate model for a given situation. A decision support tool was developed. It classifies the various models according to the type of phenomena, the physical state of the substance involved, the type of effect of interest. For each configuration, a pertinence level is defined together with the validity limits of the model and most typical assumptions.

1.3. Chemical databases

The major accidents, as they are defined in the SEVESO directive always involve hazardous chemicals. The modelling of accident consequences implies that the physical properties of the substances involved in the accident be known. PRIMARISK® contains its own chemical substances database which directly provides the needed data to the models. Of course this database is not exhaustive and it will evolve permanently during years. This will be done by letting the possibility to certified users to enter their own data and share them with the rest of the users. A validation process is being devised to avoid the filling of the database with erroneous data. However, these aspects of content validation are one of the key aspects of the success of such a project. They will be further discussed in paragraph 11.

1.4. Decision support and land use planning

One of the aims of making the knowledge available is to allow for a better debate among the stakeholders. To achieve this goal, the basis of the land use planning decisions should be explained. This is somehow done in the general knowledge section where relevant articles explain the structure and objectives of the legislation and legislative process. But the system could be used further as a true support tool for the debate between the technical stakeholders and the public actors. Multicriteria decision systems could be proposed to establish the priorities in land-use planning, for example. The system would not provide a predefined decision grid but rather help the users defining their own and, by this way, progressing in their definition of risk acceptance.

GIS tools for the representation of risk zones around industrial sites could be also proposed. Such tools have been developed in the framework of the ARAMIS project.

6. Evolution towards a true knowledge management

The elements presented in the previous paragraphs, the structure and the content of the resource platform constitute a first step towards the implementation of a knowledge management system for the control of major accidental hazards. Yet the knowledge management approach could go far beyond, as many authors agree to consider that information technologies and web based tools are only a part of the KM philosophy. In fact knowledge management could aim at a permanent capitalisation of the knowledge of all the actors of risk management who all are potential future users of PRIMARISK®.

Figure 3 represents the steps of the evolution towards a full knowledge management tool. The first step, the formalisation of expert knowledge corresponds to the writing of the Ω reports. The second step, the development of tools and databases from this initial knowledge is the first aim of PRIMARISK®. The next step involves the sharing of knowledge by future users. It could begin by the sharing of data: data about chemical substances, data about hazardous equipment, modelling hypotheses. This would be relatively easy to do on a technical aspect but would raise a series of legal issues about responsibility, intellectual property and the control of the quality of the data.

A further step would be to propose the users to provide the system with information about accidents or equipment failure with the objective of producing the lacking data for probabilistic risk analysis. Accident databases exist such as the European MARS[5] or the French ARIA[6]. Their feeding is done by the authorities on the base of mandatory declaration by the plant operators. Yet the useful information is often not available, and no quantitative treatment of the data is possible. Going further and proposing a structure for voluntary declaration would allow to obtain more information. The missing data are frequencies of initiating events, failure rates of safety barriers and safety integrity levels as defined by the IEC 61508 [6] and IEC 61511 [7] standards. Obtaining this information would require to process the raw data produced by the users. Information about the damages caused by accidents would also be useful to assess the potential impact of future accidents. But the way will probably be long before being able to get voluntary declaration of accidents by the industry in a system hosted by a third party.

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[5] http://mahbsrv.jrc.it/mars/Default.html
[6] http://aria.ecologie.gouv.fr

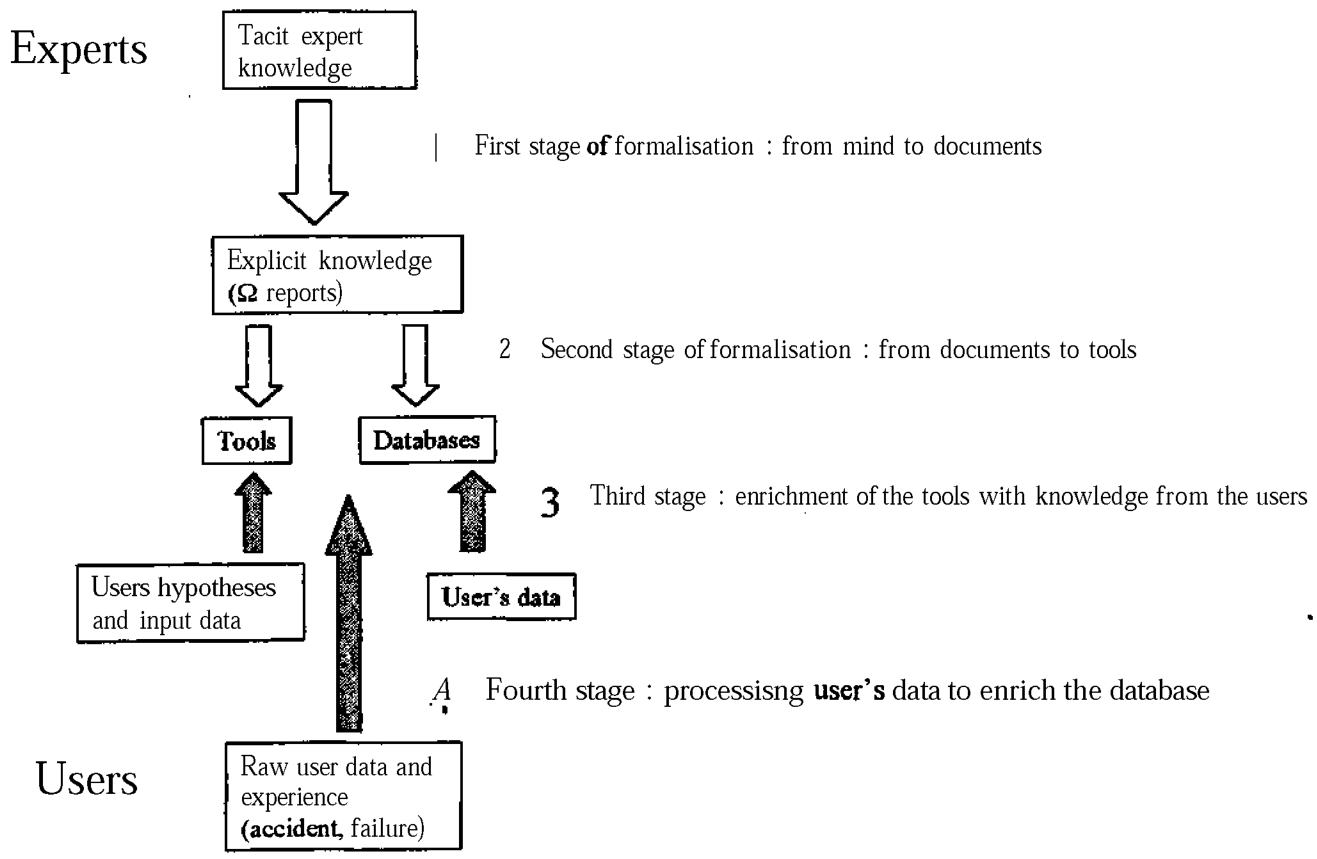

Figure 3 : four stages of the implementation of a knowledge management system

7. Obstacles to the development of an open knowledge management approach

Making knowledge available is not as straightforward as it may appear for numerous reasons. Among the various question it raises, one of the most critical is related with the responsibility and the validation of the contents. When a user visits the site of a reference institution such as INERIS, he expects to find trustable and validated information that he will be able to use to control the risk in his plant or system. Therefore, the process of formalisation of tacit knowledge of experts has to be controlled in such a way that only stabilised and proofed information be made available. This, somehow, hinders the free feeding of the platform by a community of experts and, later, by a community of users. Methods and procedures have to be developed to validate the content and guaranty to future users a safe use of the data.

Legal aspects also have to be considered. Different points should be examined.

- the property of the information provided to the system by the users;
- the responsibility of the users or that of the system operator in case of abusive use of the data;
- the confidentiality of the data.

Other issues are raised by such a system and are somehow related to the structure of responsibility around Seveso sites and the position of the various actors. The legislation requires that the plant operator do a risk analysis of the plant and produce a safety report. The competent authorities assess the validity of the report. At this step, the report can be accepted. Or, if it is considered as incomplete, complementary studies can be demanded. The administration also has the possibility to ask for an independent expertise on the validity of the risk assessment. This kind of third party expertise is increasing regularly as the administration has more and more difficulties in assessing documents that have become relatively complex. Very often the conclusions of this expertise are taken as the reference by the administration, which raises questions about the interest of the first step of risk assessment. Somehow, having a system like PRIMARISK® would be a solution for reducing the need of such third party expertise. The administration would have all the elements for assessing the validity of the initial document. But it also raises new risks.

The legislation do not impose the tools that should be used at the different steps of risk assessment and many models are currently available and used by plant operators and consulting firms, who also have developed their own tools. If the conclusions of the debate following the accident in Toulouse had insisted on the variability of the results obtained in the risk assessment process, the origin of this variability was more attributed to a lack of expertise in the use of the tools rather than to the poor quality of the tools themselves.

What will happen when the administration have reference tools at hand ? Will the studies made by alternative models be accepted ? What kind of information should be given to prevent that PRIMARISK® becomes the unique reference system ? All these questions still have to be assessed and answer clearly before the final dissemination of PRIMARISK®.

More generally, the development of this tool may imposes to redefine the position of the expert, the administration, the plant operator and the other stakeholders in their relation to knowledge and the use of this knowledge for risk management.

8. Conclusion

The debate that followed the accident in Toulouse on September 21st 2001 has underlined the necessity of a better sharing of knowledge among the various actors of risk management around hazardous industrial plants. To answer such a necessity, a four stage knowledge management scheme is proposed. The first stage involves the formalisation of the expert knowledge into documents made accessible on the INERIS web site. The second stage is dedicated to the conversion of these documents into tools and databases to constitute the base of a resource platform : PRIMARISK®. The third and fourth stage involve the sharing of knowledge by the potential PRIMARISK® users : administration, plant operators, consulting firms. At first by making their data available, and then by feeding the system with more sensitive information such as exemplary accident or, what may be more useful, incident description or data about equipment failures, allowing for a processing of these elements and the production of data needed for the risk analysis.

Implementing this knowledge management scheme raises a number of difficulties mostly related to the position of the actors of risk management, future users of PRIMARISK®. These questions are relative to the legal responsibility induces by the providing of such resources, the risk of defining a monolithic reference that would be considered as the only valid approach by the administration, the difficulty of making users share information about a sensitive subject such as risk. Somehow, the implementation of PRIMARISK® and its use question the role of experts and more generally of the actors involved in the risk management process.

Acknowledgements

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References

[1] F.Loos, J.Y.Le Déaut, rapport fait au nom de la commission d'enquête sur la sûreté des installations industrielles et des centres de recherche et sur la protection des personnes et de l'environnement en cas d'accident industriel majeur, Assemblée Nationale, 29 janvier 2002 accessible on http://www.assemblee-nationale.fr/rap-enq/r3559/r3559-01.asp

[2] G.Y. Kervern, Eléments fondamentaux de cindyniques, économica, Paris, 1995

[3] Hourtolou D. 2002. ASSURANCE - Assessment of the Uncertainties in Risk ANalysis of Chemical Establishments. U.E. Project U.E. ENV4-CT97-0627. Rapport final opération a DRA-07. *Ref. INERIS-DHo-2002-26824*

[4] Loi n° 2003-699 du 30 juillet 2003 relative à la prévention des risques technologiques et naturels et à la réparation des dommages, JO du 31 juillet 2003, accessible on http://aida.ineris.fr

[5] ARAMIS user guide, ARAMIS consortium, 2005, available at http://aramis.jrc.it

[6] IEC 61508, Functional safety of electrical, electronic and programmable electronic safety-related systems, parts 1-7. International Electrotechnical Commission, Geneva, 1998.

[7] IEC 61511, Functional safety instrumented systems for the process industry sector, parts 1-3. International Electrotechnical Commission, Geneva, 2001.