RISK MATRIXES COMBINING PROBABILITY AND TIME SCALE FOR SHORT AND LONG TERM SCENARIOS FOR CO2 LEAKAGE

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It is necessary to undertake a systemic approach in order to assess the risks of CCS, and to have an overview of the acceptability of a given project. Due to its history and skills, INERIS combined its knowledge of underground storage operations, industrial safety, environmental and health risks, in a multidisciplinary approach to achieve this goal. A specific method was therefore developed, with the idea of enlarging the principles of industrial safety and adapting them to underground processes.

The first step consists of identifying the relevant risk scenarios, based on a literature study, collection of expert advice and consideration of past incidents (learning from experience). An overall typology of 10 final “impacting phenomena” was defined for an on-shore storage in a deep saline aquifer. They gather all possible exposure routes for man and for the soil/water environment, and they combine short-term and long-term effects, such as: sudden release at surface level, mechanical effect, pollution of an aquifer by CO_2 and by impurities, etc. Each possible cause for such an “impacting phenomenon” defines a risk scenario and is represented in a fault tree software [Farret, 2010]. Top scenarios were then defined after a multicriteria analysis, for further assessment.

These risk scenarios were estimated with an innovative 4-criteria analysis that combines state-of-the-art in industrial safety, probabilistic assessment and risk management frameworks. The two main criteria that are usually considered in industrial Risk Analysis are :

i) Severity of effects on potential targets at stake. It was estimated with adequate modeling tools that predict the intensity of effects – e.g. CO_2 or brine migration, mechanical uplift, etc.
ii) Probability of occurrence, e.g. annual frequency – this frequency was estimated in a semi-quantitative manner, given the passed observation of processes and events.

Here we considered two additional criteria :

iii) Time scale. Indeed the probability of occurrence of events depends on the time scale, since an event that is very unlikely during injection phase (e.g a seism) can become very likely in the longer term. In order to simplify th analysis, criteria ii) and iii) are combined within a new criteria illustrated by Table 1 below.
iv) Uncertainty. Estimating the uncertainty is highly desirable in order to manage the risk, especially in the CCS context where learning from experience is rather poor and lack of knowledge is therefore possibly high, especially in the longer term. In order to remain easy to handle by decision makers despite the possible interaction of various processes, a global and semi-quantitative grid was defined to handle uncertainty, by including expert estimates and quantitative calculation with numerical models whenever possible.

Table 1 : Probability criteria, integrating time scale and life stages of the storage

	1	2	3	4	5
Definition	**Very unlikely during exploitation, Possible at long term**	**Very unlikely during exploitation,** AND/OR **likely during long term storage,** but not certain.	Event that is likely to happen **once or several times during exploitation** OR **certain in the longer term**	**Very likely during exploitation** (about once a year)	**Certain, even in the short term. Chronic events**
Expert advice / Passed observation	**Never observed at the world level, but not impossible given our present knowledge**	**Predictible event, but that comes back once every 1000 years only on one given site**	Évent that comes back every 10 to 100 years OR that appears inevitable in the long term	**Évent that comes back about every year (every 10 years maximum) or even several times a year**	**Current or chronic event in normal exploitation (each month, each week…)**

A practical application of the method to the injection phase and the long-term storage in a saline aquifer will be presented. It will include the risk scenarios encountered in the successive life stages of the CCS chain and the different kind of equipment involved, both at surface and in the underground. Figure 2 gives a simplified view of the final matrix, including uncertainty in the last part (right).

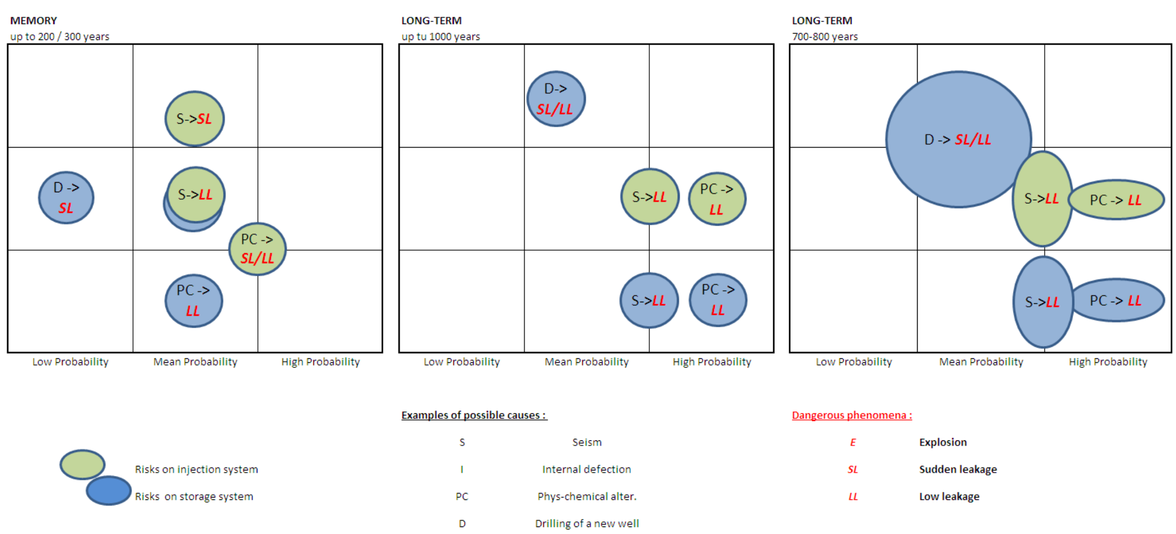

Figure 1: Example of risk matrix: i) memory phase, ii) long-term, iii) long-term with uncertainty

The final objective of this method is to demonstrate how the adequate risk management measures can reduce either the probability or the severity of risk scenarios. In this respect, the paper will show that combining fault trees and risk matrixes is relevant and efficient.

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