

Carbon Capture and Storage: Risk Management framework as a key challenge

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OXAND group is an independent international consulting company providing innovative services in expertise and risk management for Oil&Gas CCS or EOR activities. OXAND group operates its own innovative tools and databases (Simeo™) for diagnosis and prognosis of ageing infrastructures. With an experience in decision-making criteria based on performance and risk™ assessment methodologies (P&R™), coming from its nuclear experience, OXAND group develops its activities worldwide and its services are successfully acknowledged by oil&gas operators.

CCS and risk management as decision making support

The CCS technology is available today, offering a clean and reliable form of electricity supply. However, full-scale demonstration projects are urgently needed to address issues of scale-up and integration, and help shape the necessary policy and regulatory frameworks. As with other new technologies, the early deployment of commercial-scale CCS projects will involve substantial costs and risks. They are long-term in nature, requiring potentially long periods of operation (30-50 years) and abandonment (more than hundreds of years). Therefore, there is an urgent need to establish a set of solutions that will deal with the risks and remove the uncertainty that represents the barrier to their commercial-scale deployment.

CCS processes create a suite of technological and non-technological risks causing impacts on facilities, environment and/or public health and safety. CCS project life-cycle comprises three distinct phases, each of which lends the potential for risks:

- **Phase 1: Carbon Dioxide Capture**

Improper venting of CO₂, leakage at the capture point, other technological failures or catastrophic weather events may result in ecological, human health, supply chain interruptions and property-related consequences.

- **Phase 2: Carbon Dioxide Compression and Transport**

The potential for leaks during the transport of carbon dioxide from the point of generation (capture) to the sequestration (storage) site exists. Eventual transportation networks likely will travel through a combination of heavily populated areas, as well as potentially ecologically sensitive areas. Further, the corrosive nature of carbon dioxide when mixed with water under certain conditions such as colder climates may contribute to the risk of pipeline fractures. Such leaks may result in ecological, human health, and property-related consequences.

- **Phase 3: Carbon Dioxide Geological Storage**

Storage of carbon dioxide involves a series of four main steps: (1) site characterization/feasibility/design, (2) operation (carbon dioxide compression and injection) (3) closure/post-closure, and (4) abandonment. Possible local impacts resulting from injection operations or leakage but are not necessarily limited to: (i)

Acidification of potable aquifers and/or soils (ii) Accumulations of gaseous CO₂ at the surface affecting human health and/or the environment (iii) induced seismic activity or uplift.

Compared to the capture and transportation phases, the underground nature of the containment zone include large uncertainties implying more difficulties to define means by which the facility can monitor and evaluate operational conditions and the continued integrity of the containment zone. Indeed, the capture and transport processes span over relatively short periods of time, enabling an accurate simulation and precise evaluation of their performance. The storage on the other hand spans over long (5000-10000 years) periods of time and predicting the outcome is a difficult task. If in many cases the geology can be reasonably assumed to ensure its confining role by definition (exhausted oil and gas reservoirs, deep saline aquifers), a similar evaluation cannot be made for the wells unless a clear understanding of the ageing and chemical aggression processes of their components are well understood. Moreover, an important level of uncertainty always remains.

Risk management process represents the process of assessing, monitoring, mitigating and communicating risks during the lifetime of a CO₂ capture and storage facility. Risk management provides an efficient tool as decision making support for project managers and/or stakeholders involved in CCS projects by taking account the uncertainty and its effect on achieving objectives and assessing the need for any action. OXAND proposes solutions for structuring and implementing a Risk Management framework associated based on the Draft International Standard ISO/DIS 31000 circulated from the European Council (2008) includes 5 activities:

- establishment of the context
- risk assessment
- risk treatment
- communication and consultation
- monitoring and review

Well integrity assessment in CCS projects

For a commercial scale deployment of CCS technologies, barriers remain to be overcome in relation with the specificities of CO₂ geological storage: (i) storage must be ensured over a very long time frame, (ii) physical properties of CO₂ may change rapidly along a leakage path, due to phase changes, and (iii) uncertainties will always remain in the description of the geological environment. CO₂ storage will be designed for no leak over the project lifecycle, which implies maintaining sealing through wells. This appears as one of the main technological problems as this man-made intrusive object can directly connect CO₂ to water resources, biosphere, or atmosphere. In a CO₂-based environment, casing corrosion and cement leaching processes will affect well integrity. The performance of the well to confine CO₂ gas within the reservoir may be impacted and risks associated with CO₂ leakage over the storage time period may increase.

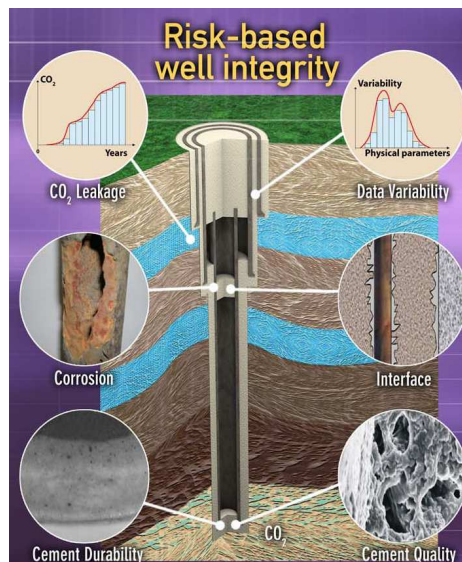


Figure 1: Illustration of well integrity key indicators

The fundamental questions we need to answer are:

- **Can wells be a CO₂ leak path to targets (atmosphere, potable water, fauna, flora, saline aquifer...)? What are the weakness points in well system to ensure well integrity performance (i.e. CO₂ leakage)?**
- **What are the key indicators of long term performance for well integrity in a CCS project?**
- **What are the risks associated to well integrity for CCS projects?**
- **What are the possible options to mitigate risks to an acceptable level?**
- **What could be the recommendations for the monitoring well integrity during injection period?**
- **How can a strategy for well abandonment be adapted to CO₂ storage?**

To answer these key questions, OXAND has developed a risk-based approach for well integrity performance management. The approach, based on Performance and Risk methodology (P&R™), serves as a decision making support tool. This methodology is based on experience in material aging and risk assessment of complex systems, like nuclear structures, where probabilistic simulations are performed. It accounts for the main stakes involved in well integrity management (economic, pollution, safety and health, corporate image, public opinion ...) and enables the full integration of uncertainties as part of risk estimation. The methodology greatly improves common approaches based on “Features, Events, and Processes” as it quantifies risk levels. It provides useful and reliable tools to support decisions for well integrity management strategies or emergency plans. Moreover, updating risk assessment with incoming data allows for an evolving vision of risk levels to optimize interventions in time.

A P&R™ analysis requires 3 major steps, presented in the Figure below:

- **Risk-based foundation** including data collection, system description, functional analysis and consequence grid
- **Performance and risk assessment:** static model, failure mechanism identification, dynamic model, scenario identification, leakage simulations and risk estimation
- **Risk treatment:** risk evaluation, risk sources identification, recommendations for reducing unacceptable risks



Figure 2 : Workflow of the P&R™, the data collection and interpretation is made in collaboration with Schlumberger Carbon Services

Leakage simulations are performed from a coupled modelling integrating 2-phase flow and ageing models. This coupled model use boundary conditions provided by a reservoir simulator of CO₂ saturation and pressure. Model parameters, such as corrosion rates and cement degradation can be calibrated through laboratory tests, including accelerated testing and time-lapse well integrity monitoring measurements. Figure 3 below shows a curve representing CO₂ leakage mass vs. time for a given scenario (Simeo™ Stor). Some illustrations of CO₂ leakage pathways over time from water saturation of well components within well system are also represented.

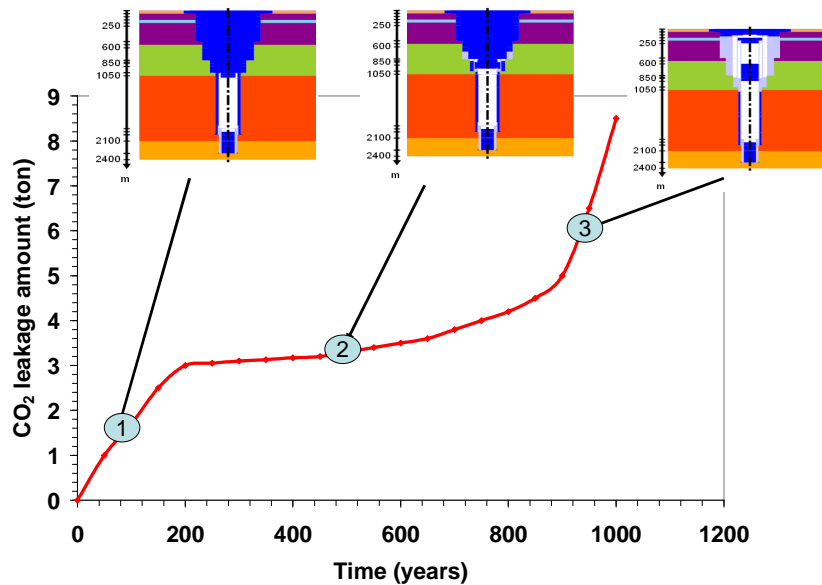


Figure 3 : CO₂ leakage mass vs. time for a given scenario (Simeo™ Stor), including leakage pathways over time (CO₂ is colored in white)

Quantifying the risk level for all scenarios enables to provide a map of all risks, a process called risk mapping. It gives a general picture of the risks at any given time of interest (injection, post-injection, abandonment). Such risk mapping constitutes a powerful support for the operators to predict and communicate on the well integrity performance. Practically, the risk mapping is performed by filling a color coding grid with each couple (frequency of occurrence, severity) corresponding to all scenarios which lead to CO₂ leakage. Figure below gives an example of such an output for a well integrity project over long term.

		Severities					
		Minor	Low	Serious	Major	Critical	Extreme
		1	2	3	4	5	6
Frequencies	6	12	0	0	0	6	0
	5	22	6	31	45	23	9
	4	13	277	151	24	10	5
	3	5	306	45	12	15	0
	2	0	36	87	46	5	0
	1	0	0	21	14	0	0

- - - Acceptable risk level

Figure 4 : Illustration of a risk matrix for a risk-based well integrity analysis. A thousand of scenario has been estimated. In each box the number of scenario that have the same frequency and severity.

By defining a Risk Acceptable Level, it is possible to identify which risks needs to be mitigated. For these unacceptable risks, the identification of the components characteristics that contributes to the highest risk scenarios (i.e. risk sources) will be the basis for the risk mitigation plan. Risk mitigation actions can either contribute to lowering the probability of occurrence, the severity of a CO₂ leakage, or both. Risk mitigation actions are of four types:

- Characterization/inspection actions
- Workovers
- Operational best practices
- Monitoring to control the evolution of the system and allow identification of a potential hazard before it occurs

Conclusion

CCS is an available technology to contribute to limit greatly the problem of climate change. The difficulties embedded in the full scale application are related to risk management. We are talking about risk management for injection period and also for long term safety demonstration of the storage. These concerns are close to the ones faced by the nuclear industry.

OXAND has successfully applied its know-how and technologies to the CCS applications worldwide. One of those technologies is the P&R™ methodology integrated in Simeo™ Stor simulator platform. It provides risk-based solutions from predictive CO₂ leakage modelling tools for well integrity performance over short term (tens of years) and long term (hundreds of years and more).

Risk-based solutions present an important growth in practice because of their capability to communicate easily recommendations considering owner stakes. Risk-based approaches offer a great opportunity to risk managers to anticipate their risk and to engage relevant programs and demonstrate long term safety.

References

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