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Public abstract

This report is part of the research project MiReCOL (Mitigation and Remediation of CO_2 Leakage) funded by the EU FP7 programme. The research activities aim at developing a handbook of corrective measures that can be considered in the event of undesired migration of CO_2 in subsurface reservoirs. This report summarizes the work performed in Task 9.7 and provides an overview of current knowledge gaps and novel remediation technologies for CO_2 well leakages. Data is always crucial to build a knowledge based approach for identify gaps for corrective measures of a problem.

Well integrity experience from the oil and gas industry has been the major source of information for this study as there are still very limited data available from leaking CO_2 wells. The corrosive environment of CO_2 wells give specific challenges to the well infrastructure including tubular annular cement.

Typical well lifecycle issues for a leaking CO_2 well are given together with an overview of knowledge gaps and technology status for remediation. Well diagnostics, novel materials, re-installation techniques are among the key gaps. Lack of relevant CO_2 well integrity data is a major area of concern for further assessment of knowledge and technology gaps. Full scale well experiments of new formation sealing materials, as the ongoing MIRECOL field test in a NIS well, are a crucial source of information in this matter.

For the future, R&D focus should be on establishing a CO_2 well database consisting of both research experience and real field cases. Further work is also required on finding efficient formation sealing materials and squeezing techniques.

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Abbreviations

EOR	Enhanced oil recovery
NIS	Serbian multinational oil and gas company
NORSOK	Norwegian standard
O&G UK	Oil and gas UK
PWC	Perforate, wash & cement
P&A	Plug and abandonment
TRL	technology readiness level
WBE	Well barrier element
WP	Work Package

1 INTRODUCTION

This report is part of the research project MiReCOL (Mitigation and Remediation of CO_2 Leakage) funded by the EU FP7 programme. The research activities aim at developing a handbook of corrective measures that can be considered in the event of undesired migration of CO_2 in subsurface reservoirs both through geology formations and along wells. Sub project 3 (SP3) is covering leakages along the well with two work packages (WP), WP8 and WP9, covering oil and gas best practices and novel materials and technologies.

This report belongs to WP9 with task 9.7. The objective of this task is to give an overview of current knowledge and technology gaps as a basis for further development of novel remediation solutions. While focus is on active CO2 wells, also subjects related to the drilling and abandonment phases are discussed briefly.

Data are always crucial to build a knowledge based approach for identify gaps for corrective measures of a problem. The amount of relevant CO_2 well integrity data is still very limited, therefore well integrity experience from the oil and gas industry with expert judgement of additional CO_2 impact are used in this report.

2 ASSESSMENT OF CURRENT KNOWLEDGE AND TECHNOLOGY GAPS

To be able to define knowledge and technology gaps of leaking CO_2 wells one needs to understand the entire well lifecycle with well processes and well barrier element functions. CO_2 wells differ from traditional oil and gas wells as creating a potentially more corrosive well environment with a perceived higher risk for well leakages.

Focus of this report is on active wells including well intervention and workover phases. This chapter consists of two sub-chapters discussing issues for consideration related to CO_2 lifecycle well operations with current remediation gaps of leaking wells.

The drilling phase is excluded and needs to be treated separately as for example blow-outs are not considered as a traditional well leak. It should however be mentioned that uncontrolled leaks from wells using CO_2 for EOR purposes have been experienced during well intervention and lost well integrity due to corroded well tubular. Such leaks containing CO_2 have been seen to escalate into an uncontrolled well as a blow-out. Those blow-outs can be violent with uncommon consequences as destroyed BOPs due to hydrate particles in the well stream and frozen surface equipment.

2.1 Well Integrity Issues

Figure 1 illustrates a lifecycle flowchart for a CO_2 operating well. The blue and dark grey boxes refer to disciplinary responsibilities and issues for consideration for the production and drilling departments of the well operator respectively.

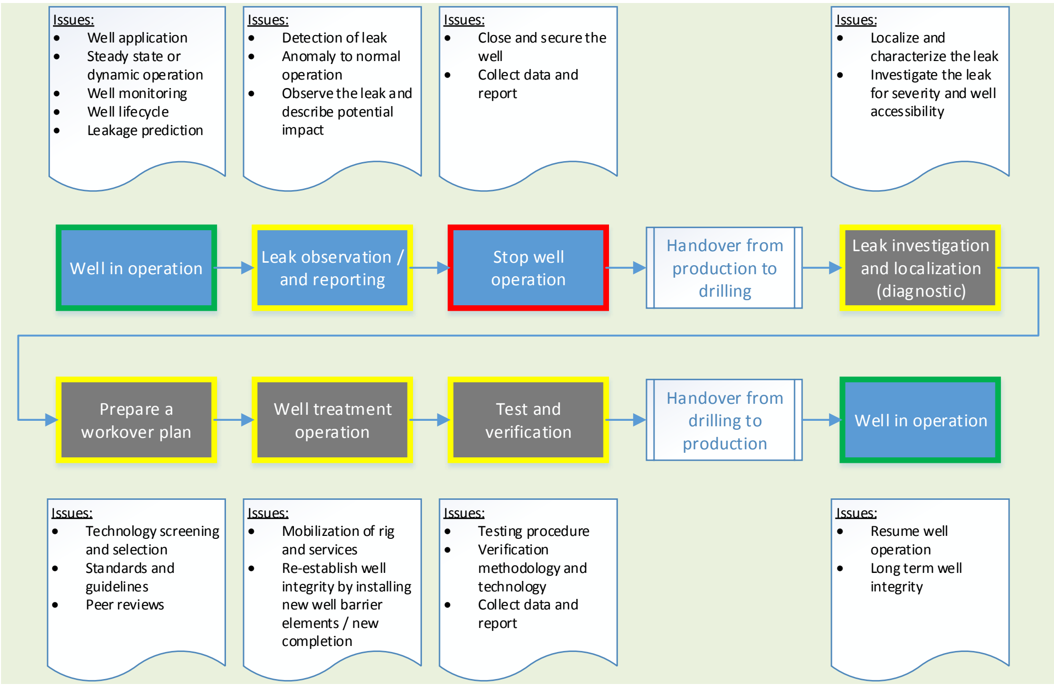

Figure 1 Well lifecycle and issues related to a leaking CO_2 well.

The “traffic light” colored lining of the boxes indicates the operability of the well. Green indicates normal operation, yellow indicates investigation and treatment while red indicates suspension of well operations.

2.2 Synergy with Oil and Gas Wells

There are several knowledge gaps related to CO_2 well integrity and some of them are discussed in this chapter. As mentioned earlier, integrity data on such wells are crucial to identify gaps and as input to R&D for corrective measures. At this stage, general oil and gas well integrity experience and expert judgment need to be used.

Conducting studies with laboratory and field scale experiments are essential to reduce gaps that are unknown to the CO_2 society. The MiReCOL (Task 9.2) field testing of a CO_2 formation sealing material at the NIS facilities in Serbia is an important event in this respect.

Major incidents and accidents in the oil and gas industry like the Macondo blow-out have led to more attention on life cycle well integrity issues. Professional societies and organizations like the Society of Petroleum Engineers (www.spe.org), Norwegian Oil and Gas Association (www.norskoljeoggass.no/en/) and Oil & Gas UK (www.oilandgas.co.uk) are important arenas for knowledge sharing of this subject. Standards and guidelines are being published through NORSOK (www.standard.no/en) and Oil & Gas UK.

One challenge with public information, as also seen in the oil and gas industry, is that what is being reported and shared have a focus on success histories. There is much to be learned from failures that needs to be captured and discussed controversially. Case based and dedicated studies are therefore needed to avoid filtered data. Still, the experience from the oil and gas industry is necessary and is being used as a basis for this study.

Lifecycle well integrity is a complex issue involving well construction, production, intervention and plugging and abandonment (P&A). Well intervention techniques and retrofit systems are important measures to the industry for increased and continued well productivity. Moreover, P&A is currently an important well technology driver due to new and stricter regulations and the volume of wells to be plugged in the near future. As an example, in Norway, the Norwegian Oil and Gas Association has been arranging a yearly P&A seminar since 2011 for experience sharing and discussing novel technologies.

Important issues being focused for oil and gas P&A relevant also for CO_2 well integrity are listed below:

- Well integrity in a long life (eternal) perspective
- Well diagnostics to investigate multiple well tubulars
- Special challenges related to annular cement quality and re-installation
- Qualification of new materials as an alternative to cement
- Testing and verification of new and re-installed well barriers

2.3 Knowledge and Technology Gaps

Figure 2 illustrates a part of a well infrastructure including basic well barrier elements for a typical CO_2 well in operation. Current knowledge gaps are shown in green boxes with connected issues in black boxes.

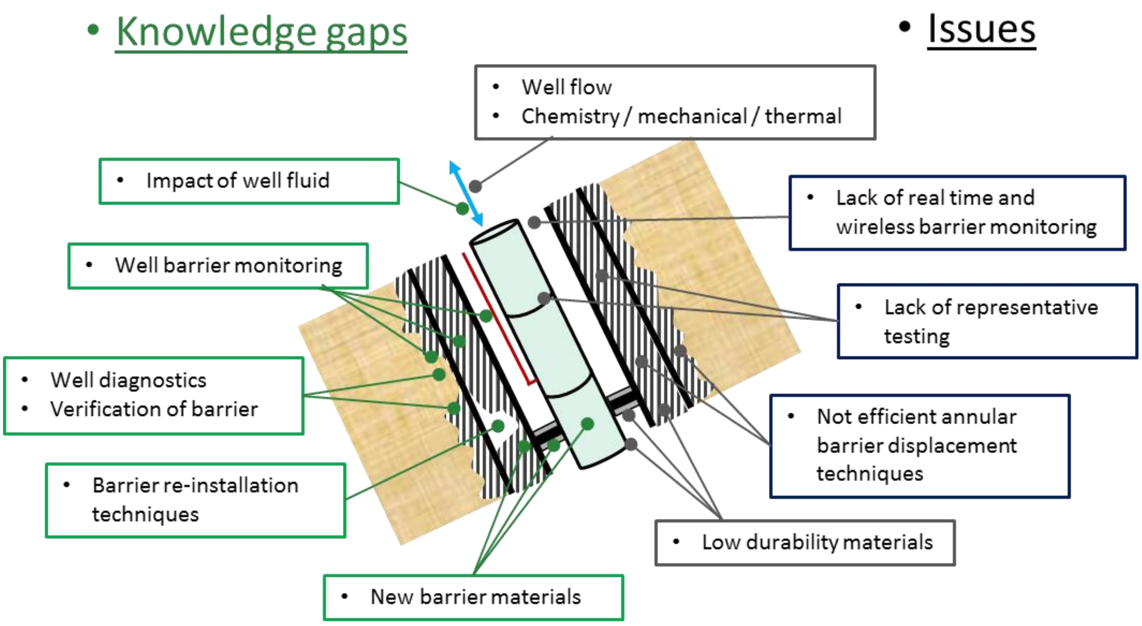

Figure 2 Schematics of a CO_2 operating well showing knowledge gaps and issues.

2.3.1 Technology Categories and Readiness Level

Important technology categories for treatment of well leakages are given below with few examples together with a high level judgement of readiness:

- Well diagnostics
  - Logging of annular cement through multiple tubulars (technology gap with ongoing R&D)
  - Characterization of creeping shale as an alternative annular well barrier and/or plugging method (case specific studies and ongoing research)
  - Downhole and surface well monitoring (ongoing engineering)
- New materials
  - Resins (existing and ongoing engineering)
  - Non-consolidating and gas tight grouts (existing and ongoing engineering)
  - Internal tubular patch (existing and ongoing engineering)
  - Platelet technology (developed for pipeline leaks, R&D for downhole applications)
- Installation techniques
  - Perforate, wash and cement run on coiled tubing (existing and ongoing engineering)
  - Rigless solutions for platform and subsea well intervention (partly existing and under development)
  - Hydraulic and control lines present at barrier depth (regulation requirement and technology gap)
  - Long and highly deviated wells with eccentric casing (regulation requirement and technology gap)
  - High energy solutions for melting tubular (R&D)
- Verification of new well barriers
  - Representative pressure testing (technology gap and R&D)
- CO_2 well integrity and reliability management system
  - Well completion database with operational history
  - Well equipment reliability database
  - System for capturing, reasoning and re-use of experience (CBR)

2.3.2 Overview of Well Integrity Issues and Related Gaps

Table 1 gives an overview of well integrity issues with related knowledge and technology gaps. Examples are also given with status and technology readiness level (TRL) as much used for R&D projects within O&G and space industry (see also Appendix A).

Table 1 Overview of well integrity issues and related gaps.

Well topic	Issue	Knowledge gap	Technology gap	TRL status	Example
Diagnostics	Annular cement	Presence and quality	Reliable measurements	TRL 0 - 2	Acoustics, electric and nuclear magnetic
New materials	Alternatives to metal and cement	Sealing capability and long life durability	Material technology	TRL 1-4	Resins
Installation	Well access and barrier placement	How and where to install barriers	Conveyance and placement techniques	TRL 2 - 7	Perforate, wash and cement (PWC)
Verification	Testing of cement bond and tubular connections	Methodology	Representative fluids and joint less tubular	TRL0	Gas instead of mud,
Monitoring	Detect leakages over individual well barriers	Methodology	Real time monitoring of barriers behind another barrier	TRL 0 - 2	Wireless technology, acoustics and electromagnetic
Database and reasoning	CO_2 well integrity database	Mindset as such databases exist for O&G	Database does not exist	TRL 1 - 7	Well integrity and reliability management systems

3 CONCLUSIONS

Current knowledge and technology gaps for remediation of leaking CO_2 wells have been addressed and mapped in this report. Well integrity experience from the oil and gas industry has been the major source of information for this study as there are still very limited data available from leaking CO_2 wells. The corrosive environment of CO_2 wells give specific challenges to the well infrastructure including tubular annular cement.

Typical well lifecycle issues for a leaking CO_2 well are given together with an overview of knowledge gaps and technology status for remediation. Well diagnostics, novel materials, re-installation techniques are among the key gaps. Lack of relevant CO_2 well integrity data is a major area of concern for further assessment of knowledge and technology gaps. Full scale well experiments as the ongoing NIS field test of new formation sealing materials are crucial source of information in this matter. Also, worldwide sharing of CO_2 well data can be useful to develop knowledge gaps, and implement best practices and trends for remediation techniques and methodologies of leaking wells.

For the future, R&D focus should be on establishing a CO_2 well database consisting of both research experience and real field cases. Further work is also required on finding efficient formation sealing materials and squeezing techniques.

4 APPENDIX A: TECHNOLOGY READINESS LEVEL (TRL)

Technology readiness levels (TRLs) is a road map of estimating technology maturity of a project. There are different definitions are used for different applications such as military, space, oil & gas, etc. The following definition is based on API recommended practices used in the oil and gas industry. An important milestone in R&D is TRL 4 when a new technology is qualified for first use.

Level	Development stage	Hardware development
TRL 0	Unproven idea/proposal	Paper concept. No analysis or testing has been performed
TRL 1	Concept demonstrated.	Basic functionality demonstrated by analysis, reference to features shared with existing technology or through testing on individual subcomponents/subsystems. Shall show that the technology is likely to meet specified objectives with additional testing
TRL 2	Concept validated.	Concept design or novel features of design validated through model or small scale testing in laboratory environment. Shall show that the technology can meet specified acceptance criteria with additional testing
TRL 3	New technology tested	Prototype built and functionality demonstrated through testing over a limited range of operating conditions. These tests can be done on a scaled version if scalable
TRL 4	Technology qualified for first use	Full-scale prototype built and technology qualified through testing in intended environment, simulated or actual. The new hardware is now ready for first use
TRL 5	Technology integration tested	Full-scale prototype built and integrated into intended operating system with full interface and functionality tests
TRL 6	Technology installed	Full-scale prototype built and integrated into intended operating system with full interface and functionality test program in intended environment. The technology has shown acceptable performance and reliability over a period of time
TRL 7	Proven technology	Technology integrated into intended operating system. The technology has successfully operated with acceptable performance and reliability within the predefined criteria

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