Summary record of the topical session of 13th Meeting of the IGSC

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Gas Migration

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ANNEX B: Summary of the Topical Session on Gas Migration

1. Introduction

Aims of the topical session were to gain understanding of the strategies (e.g. in terms of R&D, feasibility, optimization) put in place in national programmes to address the issues and in particular the irreducible uncertainties associated to gas. Therefore, information on work in national programmes was gathered by addressing the following key questions:

1. What are the regulatory requirements and what are their impacts?
2. What is the relevance of the gases for the long-term safety?
3. How are gases and the related uncertainties considered in the latest SA?
4. What are the remaining process uncertainties?
5. What is the strategy that has been put in place to treat the remaining issues?
6. Where do the organizations see potential to lower conservatism in the description of the gas pathway?
7. What multiple lines of arguments do you use to address the issue of gases in the safety case?
8. What are the strategic choices for the future?

Presentations from eight countries addressing the issue for the three main host formations clay, granite and rock salt as well as a presentation about the on-going EC project FORGE were given. The major discussion topics and conclusions of the session are summarized in the following.

2. Regulatory requirements

For most of the countries no gas-specific requirements from the regulator were mentioned. Nevertheless, the investigation of the impact of gases on the post-closure safety of a DGR is inherent to the high-level requirement to address and demonstrate safety concerning robustness, defence in depth, the use of conservatism in case of missing knowledge, and confidence building. There are cases, where the implementer is directly asked by the regulator, to address the issue in performance assessment as mentioned by Andra.

In some cases, regulations can strongly impact the way to assess the relevance of gases, e.g. in the German case, where the new requirement to assess a radiological indicator at the outer rim of the so-called isolating rock zone (IRZ), which is usually part of the host rock and ensures containment of the waste, increases the need for assessment of two-phase flow and the gas pathway.

3. Relevance of gases for the long-term safety

All presentations showed that, mainly, three different issues need to be considered when addressing the relevance of gases on long-term safety of DGRs, i.e. the impact of gases on the integrity of the host rock and technical barriers, the impact of gases on solute transport, and the release/migration of volatile radionuclides.

Integrity of technical barriers and host rock

Clay

The impact on integrity is the major issue addressed for repositories in clay. For HLW, H_2 from corrosion of iron is the most relevant gas (for ILW, there is also a potentially significant contribution by microbial degradation of organics). The potential transport processes are dissolution of gas in the porewater and diffusion in solution, two phase flow, pathway dilation and transport in tensile fractures. The processes diffusion and two phase flow are reasonably well understood, although for several materials no or uncertain two phase flow parameters exist. Experimental works seem to indicate the occurrence of pathway dilation, but conceptualization and modeling are still challenging. Further experiments are needed and some are on the way like the HG-D experiment in Mont Terri. Modeling attempts to simulate the effect in lab and field experiments have been shown by CSNC and benchmark modeling is performed within the Forge project. In the three clay disposal systems considered here (Opalinus, Callovo-Oxfordian and Boom Clay) for HLW the gas pressure is not high enough to cause tensile fracturing. The first or the first two processes mentioned above are sufficient to transport the gas out of the repository and avoid pressure build-up although pessimistic/conservative choices are assumed for the parameters playing a crucial role in the gas transport. These are the amount of metal, the diffusion coefficient and the gas entry pressure. In order to strengthen this safety statement WMOs have shifted increasingly their focus on the design capabilities as part of the strategy to thwart the potential impact of gas generation and transport on the host rock. Design choice such as a slow corroding container material (e.g. copper or ceramic shell) to reduce gas production and/or the establishment of an engineered gas transport system (e.g. sand/bentonite seals, which let gas through but still limit water movement) could avoid a pressure built-up in a range where pathway dilation of fracturing occurs. In addition, if the gas transport by both processes is slow, it needs to be mentioned, that in reality areas with low resistance (EBS/DZ) always exist, which would act as a supplemental pathway to reduce gas pressure. This feature can be regarded as a reserve FEP when it is not considered in the modeling approaches. These evidences support the claim that gas transport by (plastic) deformation in the clay host rocks is very unlikely for HLW. In order to validate these modeling approaches and to optimize the material design, in-situ and large scale tests (Gas permeable seal test, GAST, FORGE Megapacker) are in preparation. Should fractures and pathway dilation take place in the host rock, the integrity of the safety functions bound to the host rock would not necessarily be impaired. A sub-horizontal fracturing could be indeed more probable in a sedimentary rock and the high surface to volume ratio would restore diffusive transport. Last, experimental tests indicate that the gas-driven flow of contaminated water is very limited. A better understanding of the mechanisms inducing pathway dilation and fracturing with their intensity and in the light of the self-sealing capacity of the host rock is required to assess the safety impact of this transport.

Salt

For rock salt the situation can be different. For dry formations the amount of corrosion gas is likely limited by the availability of water. However, due to low residual pore volumes in the compacted salt grit backfill of a HLW repository, even a limited amount of gas can lead to a high pressure. In order to assess the potential impact of gas on the host-rock integrity, still significant knowledge gaps on corrosion data exist (since the data base originates from conditions where liquid water or a saturated water vapor phase are available, but not for the expected presence of water vapor at very low humidity). Regarding the transport of gases knowledge about gas permeability of highly compacted salt grit is lacking and the transport processes in the salt rock are not fully understood yet. No code is available to consider two-phase flow coupled with rock mechanics so far. If a low impact of gases cannot be shown, technical solutions like the creation of gas storage volumes are possible. In general, the design is to be optimized to limit the presence of water as far as possible. Also site-specific aspects play a role. A more heterogeneous formation as the WIPP site allows gas escape through higher permeable interlayers in bedded salt.

Granite

For the concepts in granite presented for the Scandinavian countries, the impact of gas is limited because of the very low corrosion of copper. If the canister fails and corrosion of the steel inlet occurs, the fractures in the host rock provide an (existing) pathway for gas transport. Similarly to the advanced organizations working on clay and salt, large scale experiments have been launched (e.g. LASGIT, GMT) to increase the understanding of gas in realistic in-situ conditions. Experiments with the concepts in granite have confirmed the observations reported by Andra regarding the beneficial role of the EBS and its interface (buffer/canister, buffer/rock in the case of granite) to evacuate gas without disrupting the geological formation. A side effect of this feature is the high sensitivity of the experiments to minor set-ups details, such as the presence of joints, interfaces or layer boundaries.

Release/migration of volatile radionuclides

With respect to the release/migration of volatile radionuclides mainly C-14 but also I-129 are mentioned. If these radionuclides occur in gaseous form their transport occurs via the carrier gas H_2 from corrosion, since the volumes of radioactive gases are usually low.

Clay

For clay repositories the migration of volatile radionuclides does not compromise overall safety. As shown by NAGRA model calculations with pessimistic assumptions (e.g. all C-14 converted to methane) do result in marginal dose rate increases in only two calculation cases compared to the dose obtained for the reference case from the water pathway.

Salt

For a relatively dry repository in rock salt, questions exist regarding the presence of volatile radionuclides in addition to the conceptual open questions mentioned above for gas migration. These are the effectiveness of generation of C-14 bearing gases in presence of water vapor and the fraction of I_2 in the spent fuel under repository conditions are not known. Again site specific differences mentioned above could reduce the problem, namely for the WIPP site, where the gas transport along horizontal, not interconnected permeable anhydrite layers causes long pathways.

Granite

For granite, in the case of canister failure, volatile radionuclide transport through fractures causes only marginal radiological impact.

Gas-driven solute transport

The gas-driven solute transport was shown to negligibly contribute to the dose rate for repositories in clay rock by Andra, Nagra and Ondraf/Niras , particularly because a piston effect is negligible (Andra). For rock salt the impact is considered via process couplings (rock deformation, fluid flow, gas generation). For WIPP the consideration of gas transport with these couplings is responsible for the human intrusion scenarios "waste spalling" and "direct brine release", which, however, have been shown to lead to negligible dose rates. It was also shown for granite repositories that the expulsion of contaminated water is not of relevance (POSIVA).

Other aspects

Gas generation can also cause changes in geochemical conditions. Examples are the formation of H_2 impacting redox conditions and therewith SF dissolution rate (s. below) and the formation of CO_2 (mainly ILW/LLW) which might act as strong ligand for actinides facilitating their transport. Again, strategic choices like the use of large amounts of MgO at Wipp site can restrict gas induced changes of brine to an envelope of geochemical conditions which can be predicted. Reactions of H_2 with clay can reduce its concentration in the formation and therewith keep the gradient and the diffusive flow high.

Finally, it should be mentioned that gas generation causes also positive effects, namely the potential reduction of water inflow as well as a by orders of magnitude reduced spent fuel dissolution rate in the presence of elevated H_2 pressures.

4. Increase confidence and robustness

In order to show as formulated at the Reims conference in 2000, what are the robust arguments that give us a reasonable level of confidence that gas is not an issue compromising deep disposal, several strategies are applied. Multiple lines of reasoning include the use of small and large scale as well as simple and robust models, the use of lab and field experiments (e.g. LASGIT, GAST, and others performed in Forge). Particularly for the derivation of corrosion rates the use of several different independent experiments were mentioned by Nagra (SERCO and other lab experiments). Design options/optimizations are increasingly considered to reduce the source term or/and provide gas transport pathways. The use of arguments from analogue situations like underground gas storage and natural gas reservoirs was mentioned but is so far not widely used.

As a second approach in case of knowledge gaps / uncertainties conservative assumptions are applied. This was mentioned for the use of Darcy Fick Henry laws, which are not in accordance with experiments but considered as conservative/neutral for water displacement and therewith solute migration. Conservative assumptions are particularly used for the gas source terms concerning the amount of gas produced as well as the production rates and timescales of duration. Several analyses used several pessimistic bounds of uncertainty ranges, e.g. mentioned by Ondraf/Niras. Potential migration pathways are also conservatively ignored (model uncertainty) in the safety analysis (e.g. DZ/EBS interfaces, higher porosity interlayers).

5. Position paper for IGSC

It is intended to compile examples from safety cases and to write an IGSC position paper to show that gases in the repository are not a safety issue but a knowledge issue. Such a paper should include feedback to engineering.

A discussion document will be drafted on the basis of this summary. The drafted document will be submitted to the IGSC for approval at the 14th IGSC meeting and to be presented at the FORGE workshop in February 2013.

The final paper is envisaged for approval at the 15th IGSC meeting.