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To: Strålsäkerhetsmyndigheten (SSM)
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Third input to the SSM quality assurance review of the SKB LOT project corrosion results in the autumn of 2020

On October 8 and November 11, 2020, the organisation Miljöorganisationernas kärnavfallsgranskning¹, hereafter called MKG, made two inputs to the quality assurance review that is being carried out by Strålsäkerhetsmyndigheten², hereafter called SSM, of the copper corrosion results from the LOT project experimental packages A3 and S2. On November 3 MKG answered question from SSM on the first input³.

MKG has followed the work of SSM in the quality review during the autumn of 2020 and has the following to say in this third input to the regulator.

1. Additional knowledge about rapid oxygen consumption in experiments

On October 8, in section 4 of the first input to SSM, MKG, with the support of scientific reports and articles, showed that trapped or in-leaking oxygen is quickly consumed in experiments that contain clay and air/groundwater. Recently MKG has discovered two articles that describe in more detail and try to explain how oxygen consumption was quick during the installation of the so-called FE experiment in Switzerland, where an entire tunnel became oxygen-free in a few months. The articles are attached as appendices 1 and 2 and are entitled "On the fate of oxygen in a spent fuel placement operation in Opalinus Clay, Giroud et al., Applied Geochemistry, 97 (2018) 270–278" and "On-line monitoring of the gas

¹ The Swedish NGO Office for Nuclear Waste Review (<http://www.mkg.se>)

² The Swedish Radiation Safety Authority

³ The first two inputs and answers to questions from SSM on the first input can be found here:
201109: MKG i det andra SSM-bidraget om LOT-försöket: Behov av mer korrosionsstudier
<http://www.mkg.se/mkg-i-det-andra-ssm-bidraget-om-lot-f-rs-ket-behov-av-mer-korrosionsstudier>
201103: MKG svarar på uppföljande frågor från SSM i kvalitetsgranskningen av LOT
<http://www.mkg.se/mkg-svarar-p-uppf-ljande-fr-gor-fr-n-ssm-i-kvalitetsgranskningen-av-lot>
201008: MKG bidrar med synpunkter till myndighetens LOT-granskning
<http://www.mkg.se/mkg-bidrar-med-synpunkter-till-myndighetens-lot-granskning>

composition in the Full-scale Emplacement experiment at Mont Terri (Switzerland), Tomonaga et al., Applied Geochemistry, 100 (2019) 234–243”.

MKG notes that it appears that the most extensive consumption of oxygen in the air inside the FE experiment has taken place through adsorption in the clay. This means that if there was trapped air in the gap between the copper pipe and the clay in the LOT test packages, the oxygen in the air was probably primarily adsorbed by the clay in a rapid process after the packages were sealed. But as the gap was with all likelihood fully filled with anoxic groundwater at the time of sealing, this likely does not make so much difference.

It is in any event unlikely that any oxygen from the clay in the experimental packages will have reached the copper surfaces of the central copper tubes. Either there has been an oxygen-free "air gap" between the copper pipe and the clay, or the gap has been filled with anoxic groundwater from a supply from the surrounding bedrock. In both cases, oxygen from the clay has not been able to reach the copper surface to cause corrosion. The oxygen in the clay that was not consumed by the chemical and bacterial processes after installation was consumed by bacteria when anoxic groundwater penetrated the clay and caused it to swell.

2. Some comments on the answers of SKB after the third meeting with SSM

MKG has noted the answers to questions from SSM that SKB on November 30 sent to the regulator after the third meeting with the company.

MKG notes that SKB states that both the inner and outer gaps to the rock and copper tube were flooded on February 2, 2000, with groundwater from the tube from the surrounding bedrock when the heating was started. There is nothing to indicate that this was done not done quickly. This means that the copper tube has been adjacent to anoxic ground water from the time the heating started. As MKG has clearly shown, the oxygen in any trapped air would either be absorbed by the clay or consumed by bacteria in the groundwater.

MKG notes that SKB states that there are no indications that oxygen has leaked into the experimental packages after installation.

MKG is concerned that the question by SSM to SKB asking for processes that could consume oxygen in the groundwater from the tube into the adjacent bedrock only mention iron ions (Fe(II)). This allows SKB also to focus on this possibility in the answer. But as shown in the REX experiment already in the end of the 1990s it is primarily microbes that consume the oxygen in the groundwater in the bedrock. The report is called SKB TR-01-05 and is included as appendix 12 in the first MKG input to SSM. The oxygen consumption takes only days. MKG has also informed SSM in section 11 of MKG's second input to the regulator that the reason for the rapid oxygen depletion is that microbes that primarily consume other substances are genetically also able to consume oxygen. They are called facultative anaerobic organisms. Degradation of organic matter provides the best energy exchange if bacteria are breathing oxygen. If there is no oxygen, most microbes switch to other electron acceptors with a slightly lower exchange of energy. This is why there can be microbial life in the bedrock that has not had access to oxygen for very long time scales. As oxygen respiration is constitutive in many bacteria, located in the

genes even if it is not needed due to lack of oxygen, these bacterial strains still consume oxygen when it is available.

MKG is thus still convinced that when the anoxic water from the tube into the bedrock was introduced into the experimental packages, the packages became anoxic to an extent that very little oxygen “trapped” in the packages could cause any corrosion. This is especially true of the bottom plate.

MKG also notes that SKB cannot give an acceptable scientific explanation as to why the hottest surfaces on the copper pipe or bottom plate have not been studied in detail, including metallographic cross-sections, with regard to copper corrosion. The company's claim that measurements of the copper content in the clay can replace a thorough analysis of the hottest copper surfaces on the pipes is not scientifically based. It would be especially interesting to see to what extent there is pitting corrosion on these surfaces. As this has not been done the SKB comparison of the corrosion in the LOT packages to the FEBEX corrosion is irrelevant.

MKG notes that SKB makes an uncollaborated and undocumented statement by there is only 1 µm of corrosion products left on the copper surface of the hottest pipe areas after removing the clay. A simple photograph of these surfaces after the clay was broken off could probably have revealed whether the statement has any truth. But there is no documentation at all of these surfaces in the report TR-20-14.

3. Lack of access to the most relevant SKB documents for the quality assurance of the corrosion results

At the preparatory meeting between SSM and SKB on September 19, 2020 – a meeting especially devoted to access to background documentation – SKB held a presentation in which a large number of publications were mentioned. On October 1 and 2, according to an agreement at the meeting, SKB sent in two deliveries with a number of documents to SSM which the company considered SSM could have use for in the review work. On October 28, SSM sent a list of documents the authority wanted to have access to. The list was produced on the basis of the documents mentioned in the SKB presentation at the meeting on 19 September. The intention of SSM was thus to get access to more documents than those sent in by the company voluntarily.

SKB made a new delivery of documents on 13 November, but from the list of documents that SSM has wanted access to the following eight have still not been handed over. After each document, the motivation given on October 20 by SSM for wanting access to the document is given.

- 1702938 - PIN (Project Initiation Note) LOT

(This should state the reasons for the project, define the responsibilities and document any deviations or additions to the project model instruction. Should also set out the project assurance reviews to be undertaken for each tollgate.)

- 1860884 - Communication plan KBP1019 (ver. 2.0)

(The PMP [Project Management Plan] notes that retrieval and analysis of these LOT parcels is of significant public interest, of value for SKB's credibility and the

viability of the KBS-3 concept. The PMP also notes that bentonite samples may be provided for those who make a request, but this will not be advertised. It is of interest to see how these aspects are proposed to be handled in the communication plan.)

- 1859185 - Risk list KBP1019 LOT (ver. 1.0)

(Key risks include, for example, potential damage to the coupons during retrieval. What other risks have been identified, how are they to be mitigated during the project and what learning has been reflected from previous LOT retrievals?)

- Activity plans for the copper analysis copper analysis (deliverable 1 of the copper WP)

(Understand activities planned for the copper sample analyzes.)

- Method descriptions for the copper analysis undertaken

(What method descriptions exist for the copper analysis? If these were undertaken under a contractor's QA process, how do they assure the method used?)

- 22932 - Analysis of corrosion samples from field trials (LOT), Rise Kimab AB

(To understand the copper analysis work scope specified for the contractors.)

- 23867 - FIB and TEM on copper samples Swerim AB

(To understand the copper analysis work scope specified for the contractors.)

- 1610897 - Swerea KIMAB AB, 2017, Audit report1610897

(Interested to see the focus of the audit and if there are any findings that may impact the work undertaken)

MKG notes that two of the documents on the list are those that the organisation has told SSM are particularly relevant for the regulator to access in order to understand the copper corrosion results presented in the report TR-20-14. These are the two background reports that SKB has received from the subcontractors Rise Kimab AB and Swerim with the results that are then presented in the SKB report. Only by comparing the results in these reports to the results presented in the report TR-20-14 is it possible to check whether the results are presented in a scientific way. Without the reports it is also not possible to know whether the work done by the consultants had proper scientific integrity.

On November 9, MKG contacted SSM to ask if any further documents had been received from SKB. The answer was that there are four documents, not eight, that SSM did not receive from SKB. According to the regulator, SKB has refused to send these four documents to SSM. Instead, representatives from SSM have been allowed to "browse through" them. It is unclear to MKG how this has been done and whether the consultants from Galson Sciences were also allowed to "browse".

MKG finds clearly that during the review process done by SSM, SKB appears to have withheld the reports that could provide the best scientific basis for reviewing TR-20-14 and also information on how the company intended to communicate the results. SSM has not received the two reports from Rise Kimab AB and Swerim, that MKG has said are the most important access. Thus SSM cannot fully implement the quality assurance of the report TR-20-14. The lack of these reports also makes it impossible for outside scientific peer review of the report TR-20-14.

The report in its present state cannot provide reliable scientific information on the copper corrosion that has taken place in the LOT packages S2 and A3.

MKG also wants to state again that SSM should make direct contact with the researchers at Rise Kimab AB and Swerim to understand their views on the work carried out and how SKB has reported it in the report TR-20-14.

4. The importance of SSM addressing relevant aspects brought forward by prominent Swedish expertise in corrosion science

MKG has noted that SSM has given prominent experts in corrosion science at the Royal Institute of Technology (KTH) an opportunity to present views on the SKB report TR-20-14. The comments were sent to SSM on November 23 and are attached as appendix 3. The experts have arrived at the following conclusion:

"This LOT study shows, under all circumstances, that the anoxic copper corrosion rate in Swedish groundwater is catastrophic with respect to the KBS-3 model and this conclusion can be made without further considering the radiation induced corrosion (radiolysis), stress corrosion cracking and hydrogen embrittlement."

MKG wants it to be made clear that it is important that SSM takes into account and in its work uses analysis that does not necessarily agree with the regulator's (and SKB's) present perception of the long-term integrity of the copper canister.

5. A final general remarks

MKG wants to again stress that as an organisation it has no possibility of influencing the nuclear waste company SKB to provide the necessary information and documentation necessary for a complete scientific review of the report TR-20-14. SSM is the only actor in Sweden that can do this, and MKG therefore has to rely on the regulator to act with resolve and inquisitiveness to access all the documentation necessary and understand all the copper corrosion that has taken place in the LOT S2 and A3 packages.

It is of utmost importance that all uncertainties are removed regarding the risks for the long-term integrity of the copper canisters in a repository environment before the Swedish government can make a decision on the permissibility of the licence application for repository for spent nuclear fuel in Forsmark.

Best regards,



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