

## Summary by the author

This report presents a quality assurance (QA) review of the work done by SKB to retrieve the S2 and A3 parcels from the Long term test of buffer material (the LOT experiment) at the Äspö Hard Rock Laboratory. Each LOT parcel comprises a heated copper tube surrounded by bentonite, with a number of copper coupons and various other test and monitoring instruments included in the bentonite. The S2 and A3 test parcels were recovered in 2019, after 20 years of LOT operation and SKB has analysed corrosion of the copper coupons and tubes from the parcels. The QA review has focused on SKB's copper corrosion analysis.

SKB's management of the LOT S2 and A3 project and the reports on dismantling the test parcels (TR-20-11) and analysing the corrosion of the copper coupons and copper tubes (TR-20-14) were reviewed. This provided an understanding of the reliability of the results from a QA perspective. The review found that SKB's management and QA arrangements were appropriate, meeting modern standards. SKB engaged a number of contractors to work on the project, who all have extensive experience and appropriate management systems for such work. The corrosion experts from the contractor teams worked collaboratively with SKB and co-authored the corrosion report TR-20-14.

It was found that some aspects of the way the LOT project was set up in the 1990s mean that there are limitations in terms of what can be learnt about copper corrosion. For example, the copper coupons, copper tubes and copper reference materials were not pre-characterised. This means that it is difficult to distinguish between defects associated with material preparation and machining and the effects of corrosion under LOT conditions. Also, redox conditions were not monitored so the time of transition from aerobic to anaerobic is uncertain, and there were no measurements of microbial populations in groundwater, so that no clear conclusions can be drawn on the relative effects of microbes and copper corrosion on oxygen consumption.

SKB argues that  $O_2$  was the main oxidant causing copper corrosion before the  $O_2$  was consumed, followed by a period in which aqueous  $Cu^{2+}$  may have prevailed as an intermediate oxidant. A long period of minor anaerobic corrosion may have occurred as a result of diffusion of low concentrations of sulphide from groundwater to the copper surfaces. However, uncertainty in the saturation time of the parcels and the effects of different oxygen consumption processes mean that alternative interpretations of system evolution and oxygen availability for corrosion could be made. For example, if full saturation coupled with rapid microbial consumption of oxygen had occurred before the tubes could be exposed to a significant period of increased temperature, then a temperature-dependent anaerobic process would have been responsible for corrosion before any arrival of sulphide. However, any copper corrosion by sulphide attack would far exceed the corrosion depths of penetration that have been estimated could occur by anoxic corrosion in pure water in saturated bentonite. Thus, corrosion by sulphide attack is of greater concern in safety assessments than any postulated corrosion in oxygen-free water. Also, alternative arguments do not support the observation from analysis of different LOT parcel tests conducted over different lengths of time that most corrosion appears to have occurred in the early stages of the tests when conditions are likely to have been aerobic. Thus, although it is not possible to conclude with absolute certainty that corrosion of the copper tubes and coupons occurred predominantly under aerobic conditions in the early stages of LOT, there is no evidence available from these results to suggest that SKB's interpretation of copper corrosion behaviour during LOT exposures is incorrect.