Developing a robust industrial methodology to calculate and measure carbon flux, capture and sequestration (CCS) potential in mine waste

Lead supervisor: **Professor Devin Sapsford**, School of Engineering, Cardiff University

Co-supervisors: **Professor Phil Renforth**, School of Engineering & Physical Sciences, Heriot Watt University; **Erik Ronne**, Boliden AB (Boliden) Research Manager for Sustainability; **Steven Pearce**, Technical Director/Principal Geoscientist, Mine Environment Management Ltd. (MEM)

Project Highlights:

- Determine a scientifically proven method (in an industrial setting) to calculate and estimate the CO_2 balance (flux) in mine waste, applicable to varied mine geology and storage technologies.
- Develop a robust industrial methodology for measuring the carbon flux, capture and sequestration (CCS) potential for mine sites, to facilitate integration with future regulatory requirements.
- Develop laboratory and field testing methods for robust sustainable and low cost monitoring of CCS in different types of mine waste based on previous study outcomes.
- Involvement in actively upscaling testing methods from laboratory-scale column and barrel trials to field trials, including trials at the Kevitsa mine site.
- Review the preliminary suitability of all Boliden mining operations for large scale CCS, including an assessment of waste emission potential.

Overview:

The increasing demand for metals essential for widespread deployment of net-zero technologies has led to expanded mining activities globally, resulting in significant mine waste production (tailings and rock). Effectively managing and identifying beneficial uses of this mine waste is a crucial activity for minimising environmental impacts, reducing greenhouse gas (GHG) emissions and improving sustainability metrics within the context of the circular economy. The aim of this PhD is to develop an industrial methodology that allows effective assessment of, and measuring of, carbon sequestration in selected mine waste materials occurring through mineral carbonation of silicate-rich waste. The focus of the project is on waste materials that have been produced/continue to be produced from a number of base metal ore deposits in Northern Europe. The research will require integrated assessment of various factors relevant to an industrial setting such as material characterisation, mine waste disposal techniques, CCS technology performance, environmental risk (e.g. acid and metalliferous drainage implications). Because of the industrial setting it is also important that due consideration is given to practical limitations and commercial viability as well as technical feasibility during project development.

Based on previous work completed from this research (e.g. Savage *et al.*, 2022; Shiimi *et al*., 2023), this project aims to bring new insights to the assessment and measurement of carbon flux, using both closed- and open-system experiments, in additional to field trials at Boliden mine sites.

Figure 1: Tailings storage facility (TSF) at Aitik mine site, northern Sweden. The image shows mine waste in the form of slurried tailings material that has been pumped into the open air tailings storage facility, after the mineral ore is processed. Aitik is one of the Boliden-owned mines that will form part of the PhD project, to establish a methodology for establishing and monitoring carbon capture and sequestration (CCS) through in-situ mineral carbonation in the TSF.

Methodology:

Cardiff University, in collaboration with Boliden and MEM, has been carrying out scientific research into innovative methods to measure CO_2 flux (sequestration and emissions) from mine waste, based on an applied industrial research partnership. Waste characterisation will involve detailed mineralogical, elemental, geotechnical, and geochemical analyses. Optimisation of waste characterisation requires detailed testing and review of laboratory methodologies. Closed-system laboratory experiments developed to date include bespoke sealed reactor cells and Xylem-WTW Oxitop® devices to measure CO_2 and O_2 flux. An experimental approach to laboratory analysis will be required to further optimise these methodologies for measurement of CO_2 flux. Field trials to be set up as part of the project include the design and construction of trial pads with remote monitoring equipment to include CO_2, O_2, pH, moisture content and temperature sensors, along with leachate samples collected for geochemical analysis. Field trials will be based in arctic locations in Finland and Sweden.

Possible Timeline

Year 1: Literature review, including a gap analysis applied to research to date, and assessment of the preliminary suitability of all Boliden mining operations for large-scale CCS, including an assessment of waste emission potential. Scoping analytical programme covering varied lithologies and geographies, and commencing testing. Commence analytical testing and field trials, data collection. Assessment of monitoring and measurement methodologies.

Year 2: Continue with development of analytical testing methodologies and monitoring of field trials, data collection. Assessment of monitoring and measurement methodologies.

Year 3: Development of industrial methodology for estimating and measuring CCS in mine waste.

The subject material is suitable for presentation at annual national meetings of the Environmental Mineralogy Group, and international conferences such as International Mine Water Association (IMWA), Goldschmidt, Advances in Mining Technology, International Conference on Acid Rock Drainage (ICARD) and so on. Opportunities for presentation and other skills and career development will be explored alongside weekly scientific supervisory meetings within hosting institution. Quarterly meetings will require the involvement of supervisors from all institutions. Student progress will be monitored using the established PGR system of Cardiff University, with annual reviews used to provide opportunities for reflection and access to additional support.

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.

Technical training:

- Laboratory training, including relevant health and safety, manual handling, and first aid training.

Partners and collaboration (including CASE):

While being based primarily at Cardiff University, the student would also have the option of being embedded in the MEM R&D office in Cardiff, working alongside MEM scientists on CCS projects (including the ongoing EU/UKRI-funded C-SINK project). Boliden would encourage visits to their operations (Finland, Sweden) as part of establishment and monitoring of field trials. In addition to using university laboratory facilities, it is also anticipated that laboratory work will be carried out in association with leading industry laboratories, providing support with bespoke testing.

Further reading:

Savage, R.J., Barnes, A., Pearce, S., Roberts, M., Gersten, B., Sapsford, D. and Mueller, S. 2022. Quantification of methods to assess carbonation in mine wastes – Potential implications for long-term mine waste drainage quality and ARD prediction. *In:* Edraki, M., Jones, D., and Jain, K.R. (eds.) *Proactive measures and lasting outcomes. Proceedings of the 12th International Conference on Acid Rock Drainage (ICARD)* 18-24 September 2022, Australia, p. 875-882.

Shiimi, R., Pearce, S., Savage, R., Barnes, A., Roberts, M., Schoen, D. and Sapsford, D. 2023. The development of a multi parameter respirometric laboratory testing method to estimate site-specific net carbon dioxide flux from metalliferous mine waste. *In:* Stanley, P., Wolkersdorfer, C., and Wolkersdorfer, K. (eds.) *Proceedings of International Mine Water Association, July 17-21 2023*. p. 471-476.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply.

Professor Devin Sapsford, School of Engineering, Cardiff University (SapsfordDJ@cardiff.ac.uk)

Cardiff University