Acid rock impacts on the green transition: Quantifying the scale of the problem and developing solutions

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Project Highlights:

- Quantification of a poorly constrained metal mining industry CO_2 emission source
- Development of novel solutions to mitigating this CO_2 emission source
- Contribute to the challenge of reaching net-zero greenhouse gas emissions

Overview:

Increased metal production by mining is essential for the technology and infrastructure required to achieve net-zero greenhouse gas emissions. However, metal production itself currently accounts for ~10% of global energy related greenhouse gas emissions (Azadi et al., 2020). Decarbonizing the metal mining industry is therefore a key component of strategies to reach net-zero. In turn, this requires comprehensive knowledge of the magnitude and nature of the associated emission sources, and how they can each be mitigated. Recent research has shown that the neutralization of acid mine drainage, a common mining pollution issue (Nordstrom, 2011), may dominated the carbon footprint of certain mining operations (Kołodziejski et al., in review).

This project will address the following questions:

- How do acid mine drainage related CO_2 emissions vary across ore deposit types?
- How can this CO_2 emission source be mitigated?

Addressing these questions will provide both the scientific rational and the means to tackle this CO_2 emission source.

Acid mine drainage refers to waters featuring low pH and high concentrations of dissolved metals draining mining regions. It is produced by the oxidative weathering of metal sulfide minerals commonly associated with metal ore deposits (Nordstrom, 2011). Acid mine drainage is a well-recognized major environmental impact of metal mining, but the carbon cycle consequences of this pollution are only recently being recognized (Raymond and Oh, 2009). These acidic waters are neutralized by reacting with carbonate alkalinity in the surrounding environment producing CO_2. These reactions are also commonly used in remediation approaches, leading to large CO_2 emissions (Martinez et al., 2018).

This project will assess the potential magnitude of this CO_2 emission source across a range of ore deposit types, by combining literature data with new fieldwork and geochemical measurements. These results will help inform the global magnitude of this CO_2 emission source for different metals/deposit types, enabling targeted mitigation efforts. It will further seek to develop acid mine drainage remediation techniques that can both improve water quality while minimizing the associated CO_2 emissions. Through partnership with Plan B CO_2 the commercialization of these techniques will be explored.

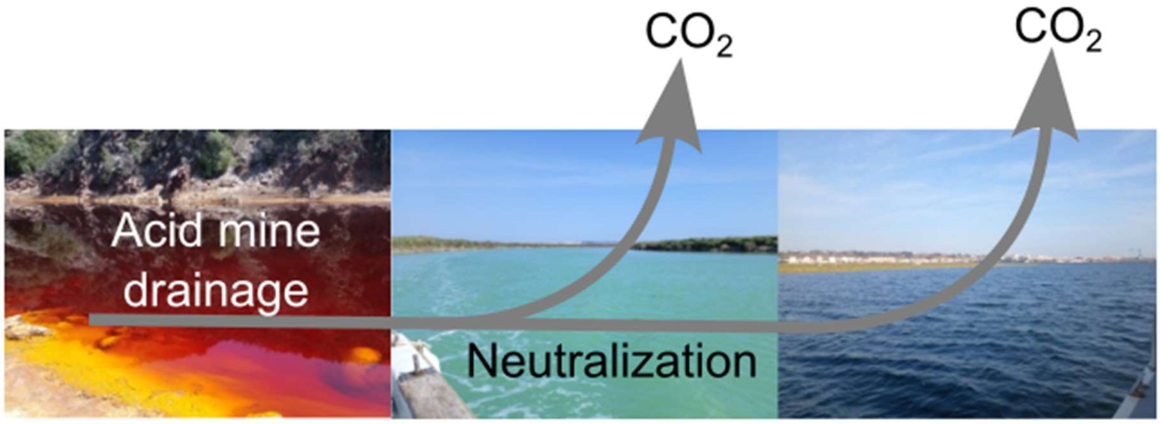

Figure 1: Three photographs of river water changing in colour from red, to green to blue A visual representation of the chemistry changes during acid mine drainage neutralization resulting in CO_2 emission.

Methodology:

Compilation of literature data for metal ore deposit compositions will be used to estimate potential CO_2 emissions by acid mine drainage based on the amount of acidity generated through the oxidation of the waste sulfides per unit metal production. Field study sites will be selected to validate these estimates, using measurements of hydrochemical fluxes. Inversion modelling will be used to constrain acid mine drainage generation rates and neutralization pathways to arrive at estimates of associated CO_2 emissions.

Laboratory experiments will be conducted to constrain olivine dissolution rates in acid mine drainage, under a range of temperature, pressure and chemical conditions. The experimental samples will be characterized by a large range of geochemical techniques, including inductively coupled plasma mass spectrometry (ICP-MS), microwave plasma atomic emission spectroscopy (MP-AES), spectrophotometry, x-ray diffraction (XRD) and x-ray fluorescence (XRF). Results will be interpreted with the aid of geochemical modelling using PHREEQC.

Possible Timeline

Year 1: Compilation of ore deposit compositional data and estimation of potential acid mine drainage CO_2 emissions per metal produced. Interpretation of estimates in context of conventional metal production carbon footprints and write-up of findings. Selection of field sites for hydrochemical measurements and logistics planning.

Year 2: Measurement of hydrochemical fluxes at selected field sites (water discharge, and major dissolved solute concentrations) at a range of seasonally varying discharge conditions. Inversion modelling to constrain acid mine drainage neutralization reaction pathways and CO_2 fluxes and write-up of findings.

Year 3: Conduct a series of laboratory experiments neutralizing different compositions of acid mine drainage with olivine, under different pressure and temperature conditions. Constrain reaction pathways in the experiments using geochemical modelling. Interpret the results in context of potential applications to passive and active acid mine drainage remediation techniques and write-up of findings.

Training and skills:

The project provides training in a wide range of skills and knowledge for addressing the environmental impacts of metal mining. These include foundational knowledge of chemical weathering and hydrology, ore geology, mineral processing and mine pollution remediation. Training will be given in a wide range of advanced analytical techniques, including ICP-MS, MP-AES, XRD and XRF, in addition to geochemical modelling. Through interaction with CASE partner Pol Knops (Plan B CO_2 BV), the applicant will gain knowledge of the commercialisation process for CO_2 removal technologies.

The applicant will become part of a vibrant research culture in the School of Earth and Environmental Sciences, with MSc, PhD and postdocs working on a range of research projects in the COASt (Climate, Oceans and Atmosphere at St Andrews) research group. It is anticipated a number of publications will arise from this study, and training in scientific manuscript preparation and presentation will be given.

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.

Partners and collaboration (including CASE):

The supervision team feature a broad range of expertise spanning chemical weathering and the chemistry of mine pollution (Luke Bridgestock), geochemical modelling (Eva Stüeken) and ore deposit mineralogy (Frances Wall). The project will be further supported by a CASE partner, Pol Knops (Plan B CO_2 BV), an entrepreneur specializing in the development of technology to reduce carbon emissions.

Further reading:

Azadi M., Northey S. A., Ali S. H. and Edraki M., 2020, Transparency on greenhouse gas emissions from mining to enable climate change mitigation, *Nature Geoscience*, 13, 100-104, doi:10.1038/s41561-020-0531

Kołodziejski S., Stüeken, E. E., Sánchez López, L, Nieto, J. M., Cánovas C. R., Pérez-López, R. and Bridgestock L., *in review,* Acid mine drainage neutralization can dominate metal mining CO_2 emissions, in review in *Environmental Science and Technology*

Nordstrom D. K., 2011, Mine waters: Acidic to circumneutral, *Elements*, 7, 393-398, doi:10.2113/gselements.7.6.393

Martinez N. M., Basallote M. D., Meyer A., Cánovas C. R., Macias F. and Schneider P., 2018, Life cycle assessment of a passive remediation system for acid mine drainage: Towards more sustainable mining activity, *Journal of Cleaner Production*, 211, 1100-1111, doi:10.1016/j.jclepro.2018.11.224

Raymond, P.A. and Oh, N.H., 2009, Long-term changes of chemical weathering products in rivers heavily impacted from acid mine drainage: Insights on the impact of coal mining on regional and global carbon and sulfur budgets, Earth and Planetary Science Letters, 284, 50-56, doi:10.1016/j.epsl.2009.04.006

Further details:

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

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