AQUA≈360: Water for All - Emerging Issues and Innovations
1-3 September 2020, Exeter, United Kingdom

The bioaccumulation of metals by algae from acid mine drainage (AMD)-a case study in Frongoch Mine, the UK

Tianhao Du [1], Anna Bogush [2], Luiza C. Campos [3], Paul Edwards [4], Peter Stanley [5]
[1,3] Institute 1 Department of Civil, Environmental & Geomatic Engineering, Faculty of Engineering, University College London, London, WC1E 6BT, United Kingdom
[2] Institute 2 Centre for Agroecology, Water and Resilience, Coventry University, Coventry, CV8 3LG, United Kingdom
[4,5] Institute 3 Natural Resources Wales, Cwmtaf, Merthyr Tudful, CF48 2HU, United Kingdom
[1]*corresponding.zczltdu@ucl.ac.uk*

Keywords: Zinc, bioaccumulation, green algae, contamination, bioindicator

EXTENDED ABSTRACT

Introduction

Acid mine drainage (AMD) refers to the deposits and tailings generated by mine site exploration and exposure to the natural environment (water, air and bacteria), which can produce acidic conditions and leach metals[1]. Algae have an essential role in the AMD environment because photosynthesis can provide nutrients for other microorganisms to keep the environment stable. Meanwhile, algae can accumulate some heavy metals [2]. This study is the first to investigate the metal accumulation by algae from Frongoch Mine (in west Wales, UK). Also, the results can not only figure out the magnitude of heavy metal contamination in the Frongoch Mine area and provide information and recommendation for AMD remediation by algae in Frongoch Mine.

Methods and Materials

Study site and samples collection

The study site of this project is the Frongoch Mine (Figure 1), one of the largest mines in North Ceredigion [3]. All the samples (AMD water and algae) were collected from four collection points around the Frongoch Mine (Figure 1)

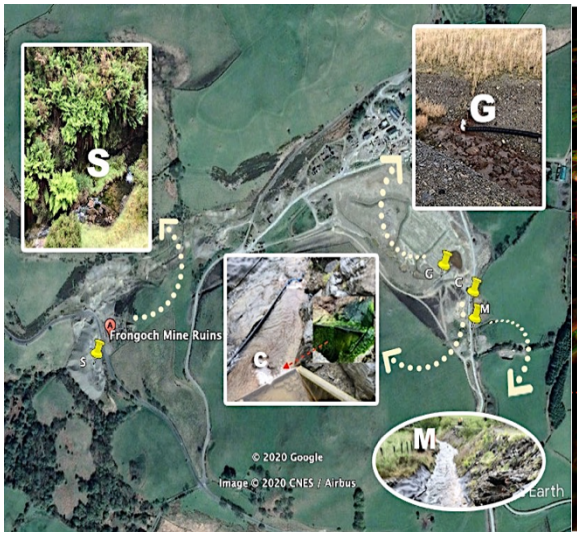

Figure 1. Four water samples collection sites in Frongoch Mine © Google and Digital Globe (2020).

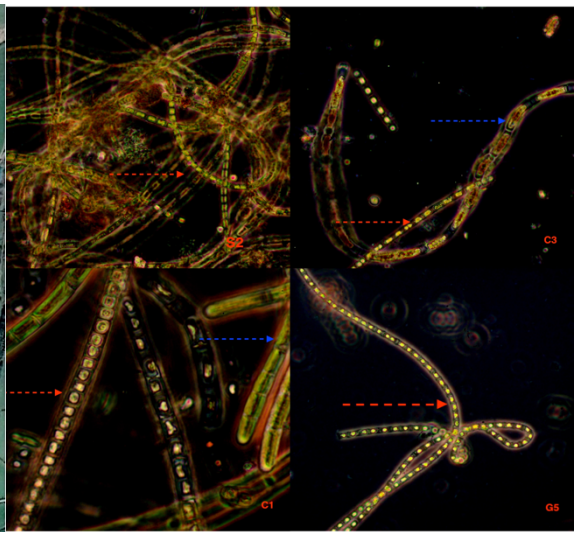

Figure 2. Algae microphotographs identification results.

Sample Analysis

All the algae samples were stored in the original AMD water and characterised by microscope (Zeiss) and then compared with literatures [4]. Two steps of water-leaching carried out the sequential metal extraction from algae by ultra-pure water and acid digestion by 70% HNO3 (adapted from [5]). pH value was analysed by a pH meter (Mettler Toledo). Metals' concentration in two steps water-leachates and digests were determined by inductively coupled plasma-optical emission spectrometry (ICP-OES) (Varian ICP-AES 720-ES).

Results and Discussion

Microphotograph's identification results show only two types of algae, *Ulothrix sp.* (Figure 2. red arrow) *and Oedogonium sp.* (Figure 2. blue arrow). In terms of metal concentration in AMD water (Table 1), Zn has the highest concentration of 351 mg/L that exceeds the General Standards for Discharge of Environment Pollutants (GSDEP) [6] 70 times and followed by Pb, Cd, Fe and Cu. Also, the metal concentration was slightly higher in the autumn sampling (S2, C2, G2) period than in summer (S1, C1, G1). This seasonal change of heavy metal concentration in AMD was also mentioned by [7], who found that the metal concentration in AMD in summer samples was higher than those collected in spring. Accumulation of heavy metals in algae decreased in the following order: Fe>Pb>Zn>Cd>Cu. Metal concentrations in algae (not shown in this abstract) from AMDs of the Frongoch Mine varied: Fe - 6.3-51 mg/g; Zn - 2.5-19.3 mg/g; Pb - 2.1-32.3 mg/g; Cu – 0.007-1.1. mg/g; Cd – 0.008-0.036 mg/g. The reason for high Fe concentration is Fe is important in algae metabolic and photosynthesis processes[8]. In terms of Pb, the difference between different samples indicates that *Oedogonium sp.* has a strong ability to absorb Pb inside the algae [9]. The lowest Cd concentration may be because a high Zn concentration can inhibit Cd uptake by algae [10].

Table 1. The heavy metal concentration of acid mine drainage in the Frongoch Mine

Metals / Samples	pH	Zn (mg/L)	Pb (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)
S1	6.19	13.8±0.25	<DL*	0.03±0.01	<DL*	0.01±0.01
C1	4.81	84.1±0.93	4.22±0.16	0.23±0.04	0.08±0	<DL*
G1	3.57	314±3.01	2.93±0.13	0.44±0.01	0.01±0	0.29±0.01
S2	6.85	15.7±0.32	0.64±0.14	0.03±0.01	0.05±0.01	<DL*
C2	4.89	139±1.85	1.74±0.14	0.38±0.01	0.18±0.02	<DL*
G2	3.46	351±3.18	3.8±0.17	0.5±0.02	<DL*	1.42±0.02
M2	6.59	7.32±0.52	<DL*	<DL*	0.2±0.01	<DL*
GSDEP**	5.5-9	5.0	0.1	2.0	3.0	3.0

*DL: Detection Limit, Zn: 0.0079 mg/L, Pb: 0.074 mg/L, Cd: 0.0044 mg/L, Cu: 0.0039 mg/L, Fe: 0.0044 mg/L.
**GSDEP - General standards for discharge of environmental pollutants (1993).

Conclusions

The Frongoch Mine has low pH and a high concentration of metals in AMD water. Metals' concentration has noticeable seasonal changes. There are mainly two types of algae living around the mine site. *Ulothrix sp.* and *Oedogonium sp*. Both of them showed great ability in metal accumulation, especially for Zn, Fe and Pb. Based on these results, both *Ulothrix sp.* and *Oedogonium sp.* be used as bioremediation and bioindicator method in Frongoch Mine.

REFERENCES

[[1] A. A. Bogush, V. G. Voronin, V. D. Tikhova, and G. N. Anoshin, 'Acid Rock Drainage Remediation and Element Removal Using a Peat-Humic Agent with Subsequent Thermal Treatment of the Metal–Organic Residue', *Mine Water Environ.*, vol. 35, no. 4, pp. 536–546, Dec. 2016, doi: 10.1007/s10230-015-0380-2.
[2] S. Orandi and D. M. Lewis, 'Biosorption of heavy metals in a photo-rotating biological contactor—a batch process study', *Appl. Microbiol. Biotechnol.*, vol. 97, no. 11, pp. 5113–5123, Jun. 2013, doi: 10.1007/s00253-012-4316-5.
[3] F. Murphy, 'FRONGOCH METAL MINE, CEREDIGION', *DYFED Archaeol. TRUST*, p. 104, Jun. 2015.
[4] H. Canter-Lund and J. W. G. Lund, *Freshwater algae: their microscopic world explored*, Reprinted. Bristol: Biopress Ltd, 1998.
[5] S. Jaiswar, M. A. Kazi, and S. Mehta, 'Bioaccumulation of heavy metals by freshwater algal species of Bhavnagar, Gujarat, India', *J. Environ. Biol.*, p. 6, 2015.
[6] GSDEP (1993), 'General Standards For Discharge Of Environmental Pollutants(Part A: effluents)', *Environmental Stand.*, vol. GSR 801 (E), Dec. 1986, [Online]. Available: https://scclmines.com/env/ENVIRONMENTAL%20STANDARDS.pdf.
[7] S.-Y. Oh and M.-K. Yoon, 'Biochar for Treating Acid Mine Drainage', *Environ. Eng. Sci.*, vol. 30, no. 10, pp. 589–593, Oct. 2013, doi: 10.1089/ees.2013.0063.
[8] N. A. Al-Shwafi and A. I. Rushdi, 'Heavy metal concentrations in marine green, brown, and red seaweeds from coastal waters of Yemen, the Gulf of Aden', *Environ. Geol.*, vol. 55, no. 3, pp. 653–660, Aug. 2008, doi: 10.1007/s00254-007-1015-0.
[9] J. K. Bwapwa, A. T. Jaiyeola, and R. Chetty, 'Bioremediation of acid mine drainage using algae strains: A review', *South Afr. J. Chem. Eng.*, vol. 24, pp. 62–70, Dec. 2017, doi: 10.1016/j.sajce.2017.06.005.
[10] S. Töpperwien, R. Behra, and L. Sigg, 'COMPETITION AMONG ZINC, MANGANESE, AND CADMIUM UPTAKE IN THE FRESHWATER ALGA SCENEDESMUS VACUOLATUS', *Environ. Toxicol. Chem.*, vol. 26, no. 3, p. 483, 2007, doi: 10.1897/06-181R.1.