Algae Bioaccumulation Capacity for Metals in Acid Mine Drainage (AMD) – A Case Study in Frongoch Mine, UK

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Abstract

Algae living in the AMD water around the Frongoch Mine, the UK, were collected and identified by microscope. Metals' concentration was evaluated in AMD water and algae in two seasons (June and October) in 2019 to assess the bioaccumulation capacity of algae. Two types of algae, *Ulothrix sp*. and *Oedogonium sp*., were found to be the main species at the Frongoch mine, and they revealed a high capacity of metals bioaccumulation. Concentrations of metals in AMD water from higher to lower were Zn>>Pb>Cd>Fe>Cu. Study results identified the bioaccumulated metals concentrations in algae from higher to lower were Fe>Pb>Cu>Cd>Zn.

Keywords: Bioaccumulation, Green Algae, Bioindicator, Metals

Introduction

Acid mine drainage (AMD) refers to the deposits and tailings generated by mine site exploitation and exposure to the natural environment (water, air and bacteria) which can produce acidic conditions and leach metals (Favas *et al*. 2016; Bogush *et al*. 2016). 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 metals (Orandi and Lewis 2013). This is the first reported study that investigates the metal accumulation by algae with accurate chemical methods from AMD of Frongoch Mine (in West Wales, UK). Also, the results can help to determine the magnitude of metal contamination in the Frongoch Mine area and provide information and recommendation for AMD remediation by algae in Frongoch Mine.

Methods

Study site and sample collection

This project's study site is Frongoch Mine (Figure 1), which was one of the largest mines in North Ceredigion (Murphy 2015).

Physical and chemical analysis

All the algae samples were stored in the original AMD water and characterised by microscope (Zeiss) and then compared with literature (Canter-Lund and Lund 1998). Sequential metal extraction from algae was carried out by two steps of water-leaching and acid digestion. A microwave acid digestion procedure was applied for the residue of algae. Metals' concentrations in two steps water-leachates and digests were determined by ICP-OES analysis.

Result and discussion

Microphotograph's identification results show there are only two types of algae *Ulothrix sp*. and *Oedogonium sp*. Table 1 shows the metal concentrations of AMDs from the Frongoch Mine. The highest Zn concentration was observed on site G that exceeded the GSDEP (1993) 70 times and followed by Pb, Cd and Fe. Metal's concentration was slightly higher in the autumn sampling (S2, C2, G2 and M2) period than in summer (S1, C1and G1). This seasonal change of metal concentration in AMD was also mentioned by Oh and Yoon (2013), who found that the metal concentration in AMD in summer samples was higher than that in spring samples.

Figure 1 The four water sample collection sites in Frongoch Mine. © Google and Digital Globe (2020).

Accumulation of metals in algae decreased in the following order: Fe>Pb>Zn>Cd>Cu. High concentrations of Zn (79.4-90.6%) in algae were found in the algae acid digest fraction, which indicates that Zn mainly accumulated inside algae. A significant Zn ratio can also be adsorbed on the surface of algae (6.4-20.6%). Pb is however mainly accumulated inside the algae, as shown by the high Pb content measured in the algae acid digest fraction (>97.5%).

Conclusions

Zn and Pb are the primary metals in the AMDs from the Frongoch Mine. Two species of algae *Ulothrix sp*. and *Oedogonium sp*., were identified can survive and accumulate metals in AMD. The results from this study identify that algae could be used as a bioindicator for the assessment of water pollution at Frongoch Mine. Based on the above results, further study may focus on examining the statistical relationship between different metals accumulation and background water from different sites to establish the pattern of metal accumulation by algae in this area. Also, factors that caused seasonal changes should be identified by more sampling and analysis.

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Table 1 Metal concentration of acid mine drainage from Frongoch Mine.

Metals Sample	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 ± 0.174	0.5 ± 0.02	<DL*	1.42 ± 0.01
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).

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