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Technical Communication

The Potential Importance of Mine Sites for Biodiversity

Lesley C. Batty

School of Geography, Earth and Environmental Sciences, Univ of Birmingham, Edgbaston, Birmingham, B15 2TT, UK; e-mail: L.C.Batty@bham.ac.uk

Abstract. Abandoned mine sites are typically viewed as environmental problems due to their negative impacts on local ecosystems. This paper presents an alternative viewpoint providing evidence of the potential importance of mine sites for supporting rare and threatened species from many of the major taxonomic orders. The potential importance of these species in remediation of polluted environments is also highlighted.

Key words: biodiversity, mine water, phytoremediation, revegetation

Mining of ores and smelting of metals may have started between 6000 and 7000 years ago (Goudie 1993). It was not until the industrial revolution in the 18th Century that individual mining activities became extensive, although these were often just expansion of existing works using new technologies. This long history of mining has contributed to, and in some cases been the sole basis of the wealth of nations, but has also left a legacy of disturbed sites. Both coal and metalliferous mining leaves large deposits of waste material as spoil heaps. Land affected by mining is often characterised by steep unstable slopes, disruption of natural drainage systems, and an absence of vegetation due to a lack of nutrients, poor soil structure, acidity, and/or metal toxicity. In addition, water infiltrating these heaps can transport metals and acidity into local watercourses. The cessation of pumping in underground workings can also result in pollution of surface waters, as rebounding groundwater transports previously oxidised mineral salts in the tunnel walls to the surface. In England and Wales alone, it is estimated that 2,500 km of streams are at risk of failing EU Water Framework Directive objectives due to mine water pollution (Jarvis and Rees 2004).

The precise nature of the environmental problems caused by mining vary, depending largely on the material mined, processing techniques used, local geography and geology, and time scales involved. However it is generally accepted that mining negatively affects the local biota, changing the natural community structure and reducing biodiversity. This is particularly true of polluted waters where severe floral and faunal impoverishment can occur in rivers downstream of the discharge (e.g. Armitage and Blackburn 1985; Jarvis and Younger 1997; Malmqvist and Hoffsten 1999). Some recovery of species abundance and diversity may occur downstream depending on the severity of the contamination (Scullion and Edwards 1980).

The importance of polluting substances in reducing biodiversity has been recognised in The Convention on Biological Diversity from the United Nations Environment Programme, which has published a number of goals to achieve a significant reduction in biodiversity loss by 2010. Included in these are the conservation of biological diversity of ecosystems, habitats and biomes, promotion of the conservation of species diversity, and the reduction of pollution and its impacts on biodiversity. Recent developments in environmental legislation within Europe have made some progress in addressing the problems of pollution affecting ecosystems, including the EU Strategy for Soil Protection (COM 2002 179) and the Water Framework Directive (2000/60/EC). The WFD became effective in 2000 and requires member states to "protect, enhance and restore rivers…to maintain or achieve good surface water status", which includes both ecological and chemical status. The assessment of whether a particular water body achieves this status is based on a comparison with 'reference conditions'. However, in many cases, it is impossible to determine what these reference conditions should be due to a lack of equivalent systems unaffected by anthropogenic influences. The term reference conditions holds a particular problem for mine sites as the pollution source may have been active for hundreds or thousands of years, and may even predate the mining activity. This long history of mining has led at many sites to the development of a unique and ecologically important community, which is dependent on the presence of elevated concentrations of metals and/or acidity.

Plant species that have adapted to metal-contaminated soils include true metallophytes, plants that are only found on metal-contaminated soils (Baker 1987), and other species that can occur on both metal-contaminated and normal soils in the same area. The latter are referred to as pseudometallophytes. The exact number of metal-resistant plant species is not known but there may be hundreds of thousands of species (Whiting et al. 2004). As outlined above, metal-contaminated soils have been available for plant colonisation at mine sites for thousands of years and so now support distinctive metallophyte floras rich in endemic taxa (Baker 1987). This has been recognised in the UK and several abandoned mine sites have been designated as Sites of Special Scientific Interest due to their characteristic metallophyte and lichen flora (Cooke and Morrey 1981). In the Peak District of the UK, ancient lead deposits support important vegetation communities containing four key metallophyte species: *Minuartia verna, Thlaspi caerulescens, Cochlearia pyrenaica, and Viola lutea*. These sites are also important for lichens, including specialised metal-tolerant species (Barnatt and Penny 2004). The importance of these communities has been recognised by their inclusion in the Peak District Biodiversity Action Plan.

The presence of mining in an area obviously reflects the presence of metalliferous ore bodies or coal seams and these can naturally contaminate local soils and watercourses prior to, or without, mining activity. For example, the landslip at Mam Tor in Derbyshire, UK exposed large volumes of pyritic shales to oxidation and resulted in contamination of waters leaching through the landslide with elevated concentrations of iron, manganese, copper, and sulphate (Batty 1999). Studies in the North Pennines in the UK showed that sites that were naturally acidic and metal contaminated prior to man's activities had the richest stream flora, and there was some indication that older sites also had a richer flora (Hargreaves et al. 1975). This highlights the importance of the history of mining within an area when considering remediation. However, it is not only the ancient mine sites that can provide ecological interest in terms of metal-tolerant flora; isolated and recent mine spoils can also support populations of metal-tolerant taxa.

The occurrence of highly adapted species is not confined to the UK. For example, the rare and threatened species, *Viola calaminaria*, has been found at sites in Belgium contaminated by atmospheric deposits from metal smelters where there were elevated concentrations of Zn, Pb, and Cd (Bizoux et al. 2004). Many of these metalliferous species are actually dependent on high concentrations of metals in soils and grow less well in uncontaminated soils. For example, the rare copper moss species, *Scopelophila cataractae*, was shown to have a higher percentage cover and larger leaves on individual plants when grown on the most highly metal-contaminated soils (Shaw 1993).

Metal-contaminated sediments may be transported from the mining site and accumulate downstream as alluvial deposits. This may be particularly prevalent where spoil heaps are unstable and remain unvegetated and therefore prone to erosion. This material may be colonised by metalliferous species in great numbers (Kerslake 1998).

The ecological importance of abandoned mine sites is not confined to the flora; such areas may also support significant populations of rare or threatened fauna. For example, a variety of bat species have been found to use abandoned mines as a roost, including long-eared bats in Mexico (Lopez-Gonzalez & Torres-Morales 2004) and lesser horseshoe bats in the UK. The lead deposits in the Peak District of the UK also provide 'hot spots' for invertebrates such as *Leptarthrus brevirostris* and *Carabus monilis* (Barnatt and Penny 2004). Mines in Australia were found to support threatened beetle species, which were rare in the surrounding agricultural areas due to human impact (Brändle et al. 2000). Although these species do not rely on the presence of pollutants as is the case for metallophytes, they tolerate them and benefit from the current absence of anthropogenic activities, such as agricultural practises and building, which may be prevalent in surrounding areas.

Microbial diversity at mine sites may also be greater than previously thought. Recent investigations of acidic mine waters in the UK isolated a group of previously unknown iron-oxidising microorganisms (Hallberg and Johnson 2003). Microorganisms may be particularly important at these sites, as they are involved in key biogeochemical cycles. It may be possible to utilise these organisms in biotechnological processes for the remediation of other metal-contaminated soils and sediments. This is also true of many metallophytes as their tolerance to, and in some cases, accumulation of pollutants can be exploited for revegetation of other contaminated sites and may also be used in phytoremediation, although the latter technology is still in its infancy. Metal-tolerant species are already used extensively in wetlands treating mine waters, although this is restricted to a small number of species. Further investigation and testing of additional naturally-occurring wetland species may help to improve the biodiversity potential of these treatment systems, whilst maintaining or even improving the treatment performance.

From this, it appears that environmental pollution as a result of mining does not necessarily result in an ecologically poor site. In fact, mine sites can be important for rare and threatened species, many of which are dependent on the very pollution that is a problem for other organisms. This raises the question of whether whole-scale remediation of mine sites to achieve ideal ecological or chemical reference conditions is the best approach. It is clear that mine sites can pose an environmental threat to surrounding land and waters, and in most cases adversely affect macro-invertebrate communities. Sites that are causing large-scale pollution of surrounding land and water in populated areas, or where land can be re-used clearly should be remediated. However, it is essential that ecologically valuable sites are not destroyed through whole-scale remediation schemes. An integrated mine site management plan that considers ecological aspects could ensure that large-scale pollution of surrounding land and water courses is prevented whilst providing areas set aside for the preservation of metalliferous fauna and flora. At present, there is not enough information on the fauna and flora of ancient and modern day mine sites in order to achieve this, and so this should be a priority research area. In particular, our knowledge of the impact on aquatic communities is largely limited to macro-invertebrates; further investigations into algae, higher plants, and microbial communities are required. By improving our understanding of the natural ecological communities associated with mining activities, we will not only be able to improve biodiversity at such sites, but may also enable more extensive use of such species in biotechnology.

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