Wetland systems associated with mine sites as a source of biodiversity

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ABSTRACT
Wetlands receiving mine drainage can occur both naturally and as engineered wetlands designed for remediation. A preliminary study was undertaken to determine the range of plant species that occur within natural and constructed wetlands receiving a variety of mine effluents. Results showed that there were a very small number of species (10) found in both types of wetland. The species composition differed between natural and constructed wetlands with the former containing a number of species not found in engineered systems. The lack of diversity in plant species raises some important fundamental questions regarding the evolution of tolerance in wetland plants. The implications of diversity in plant species are also discussed in relation to the contribution to ecosystem biodiversity.

INTRODUCTION

Biodiversity is essentially defined as the number of species in any given habitat. It has been recognised that global biodiversity is declining at a rate which is far above the background rate of extinction (Pimm *et al.* 1995). One of the main threats to biodiversity is the presence of polluting substances, which has been recognised in The Convention on Biological Diversity from the United Nations Environment Programme.

The human population has been exploiting natural resources for many thousands of years, extracting minerals for energy sources, building materials and many other applications. Before the industrial revolution, however mining activities tended to be small scale, but the processing techniques were inefficient which left large amounts of the original; minerals in the waste material. Evidence of these small scale operations can be found throughout the world. During the industrial revolution extraction and processing techniques became much more efficient allowing the expansion of mining activities giving rise to large operations such as those seen at Kimberley Mine Pit, South Africa and San Victor Mine, Spain. Although the quantities of minerals left in the waste materials was reduced in terms of concentration, the amount of waste material produced increased in line with the expansion of the mines.

It is now acknowledged that a major cause of pollution throughout many regions of the world is the release of contaminated waters from such mine sites. Mine water is considered to have a major impact upon the ecology of the local area both terrestrial and aquatic ecosystems. Mine waters have been shown to cause significant changes in macroinvertebrate communities (e.g. Jarvis & Younger 1997; Malmqvist & Hoffsten 1999), diatoms (Hirst *et al* 2002) and fish (Parsons 1977) in river systems. However the story is not as simple as it first seems.

The presence of high concentrations of metals in soils and sediments is not confined to areas which have been exploited by man. It should be remembered that the presence of metalliferous ores is a natural phenomenon and where these outcrop metal concentrations in the resulting soil will naturally be elevated. This natural occurrence has its origins in geological history and therefore will have affected faunal and floral populations long before humans proliferated. As a result there are many species associated with such sites that are able to exist on soils which contain concentrations of metals which would normally be toxic. This is particularly true of plant species which have developed a range of tolerance and avoidance strategies. In some cases plant species are only found on metal contaminated soils and are referred to as true metallophytes (Baker 1987).

Although there has been extensive work particularly in recent years on metal tolerance in land species, equivalent research into wetland and to some extent aquatic species has largely been ignored. There are a number of wetland plant species that are known to be tolerant of metals, but none of these are known to be true metallophytes. These species are know to occur in wet areas within old mine workings, at the base of spoil heaps, in wetlands which lie between mine effluents and rivers, and in flooded areas associated with rivers affected by mine waters. This tolerance to metals has been exploited in recent years in their use in engineered wetlands for treatment of metalliferous waters (e.g. mine drainage, road runoff and other industrial wastes). However, the choice of plant species largely relies upon local provenance and previous use, which has resulted in a very small number of species being used in these systems. Table 1 gives details of the most common plant species used in mine water treatment systems.

Given that it is thought that there may be hundreds of thousands of metal tolerant plant species, both terrestrial and aquatic (Whiting *et al* 2004) it is surprising that a greater number of species are not used within treatment wetlands.

Site	Country	Wetland Type	Plant species	Reference
Shilbottle	UK	Aerobic	*Phragmites australis*	Batty & Younger 2004
Woolley Colliery	UK	Aerobic	*Phragmites australis* *Scirpus lacustris* *Typha latifolia* *Typha angustifolia* *Iris pseudacorus* *Phalaris arundinacea* *Juncus effusus*	Laine 1999
Whittle Colliery	UK	Aerobic	*Phragmites australis* *Typha latifolia*	Batty *et al*. 2005
Wheal Jane	UK	Aerobic	*Phragmites australis* *Typha latifolia*	Barley *et al* 2005
Old Meadows	UK	Aerobic	*Typha latifolia* *Phragmites australis* *Scripus lacustris* *Iris pseudacorus*	www.coal.gov.uk
Falconbridge	Canada	Aerobic	*Typha latifolia*	Goulet & Pick 2001
Coshocton	USA	Aerobic	*Typha latifolia*	Lacki *et al* 1991

Table 1 Examples of plant species used in engineered wetlands treating mine waters

The presence of plants within wetlands has some impact upon the treatment efficiency of wetlands through the input of organic matter, baffling flow and uptake of metals (Batty & Younger 2002). In addition plants have an aesthetic value and may also contribute to the ecological potential of wetlands (Knight *et al*. 2001). However there have been few detailed investigations into the ecology of these systems and the response of faunal and floral communities to physico-chemical conditions within wetlands. Plant diversity may also have an impact upon other communities within wetlands. Strong relationships have previously been found in acidic river systems between invertebrate and macrofloral assemblages (Ormerod 1987). Thus the importance of plant species within wetlands may not only be important for plant diversity but may impact upon overall community diversity.

	UK Grid Ref	County/Country	Type of Mining	Type of wetland	pH	Major Contaminants
Parys Mountain 1	SH447901	Wales	Metal (copper)	Precipitation ponds (semi-natural)	3	Fe, Mn, Al, Cu, Zn, SO_4
Parys Mountain 2	SH447901	Wales	Metal (copper)	natural	3	Fe, Mn, Al, Cu, Zn, SO_4
Parys Mountain 3	SH447901	Wales	Metal (copper)	Natural (uncontaminated)	3	None
Smithy Wood	SK366958	South Yorkshire	Coal	natural	3.5	Fe, Mn, Al, Zn, Ni
Dodworth	SE313065	South Yorkshire	Coal	constructed	3	Fe
Parrot's Drumble	SJ821519	Staffordshire	Coal	natural	6.5	Fe, Mn, Al
Woolley Colliery	SE303115	South Yorkshire	Coal	constructed	8	Fe, Mn
National Coal Mining Museum	SE251165	South Yorkshire	Coal	constructed	8	Fe, Mn

Table 2 Summary information on wetland sites used for preliminary study into plant species diversity.

A full investigation into the ecology of natural and engineered wetlands receiving mine drainage was started in 2005. A preliminary investigation was undertaken to determine the range of plant species that are present in both natural and constructed wetlands receiving mine waters. This paper presents the preliminary data which will contribute to a full research project.

METHODS

Quadrat studies were undertaken in the spring of 2005 at 8 different wetland sites within the UK (Table 2). The sites were chosen to cover a variety of different mine waters.

Three 1 m^2 quadrats were taken at each wetland, one at the inlet, centre and outlet. Species within the quadrats were identified to species level and the percentage cover. It is important to note that % cover may total more than 100% due to vertical strata within the plant communities.

RESULTS

Data from the 8 different wetland sites show a very limited number of plant species that occur, with only 10 different species being identified (table 3). The species composition was different in natural wetlands when compared to constructed wetlands. *E. angustifolium, J.squarrosus, Polytrichum commune, P. natans,* and *S. cuspidatum* were only found in natural wetlands. *P. australis* and *T. latifolia* were the only species found in both natural and constructed wetlands but has a lower % cover in natural wetlands and were confined to two natural sites, Parys Mountain 2 and Smithy Wood. Only one species was found in constructed wetlands, and not in natural wetlands, which was *I. pseudacorus.*

Coverage by vegetation was variable in all sites with many sites having high percentages of bare ground. Where moss spcies occurred there was always 100% cover. Vertical layering of vegetation only occurred in natural wetlands, and only in two sites Smithy Woods and Parys Mountain 2.

Wetland		Bare	*Calluna vulgaris*	*Equisetum litorale*	*Eriophorum angustifolium*	*Iris pseudacorus*	*Juncus squarrosus*	*Phragmites australis*	*Polytrichum commune*	*Potamogeton natans*	*Sphagnum cuspidatum*	*Typha latifolia*
Parys 1	1	20	5		75							
	2				100							
	3	60			40							
Parys 2	1	50			50							
	2	25			75							
	3							25			100	
Parys 3	1	20			10					70		
	2	20			10					70		
	3	10								90		
Smithy Wood	1											
	2								100			15
	3						20		100			20
Dodworth	1	10						90				
	2	70										30
	3							100				
Parrot's Drumble	1	80		20								
	2	85		15								
	3	100										
Woolley Colliery	1	60						40				
	2	50				10		40				
	3	40										60
National Coal Mining Museum	1	30						60				
	2	90				10						
	3	70										30

Table 3. Quadrat ($1m^2$) percentage vegetation cover at inlet (1), centre (2) and outlet (3) of wetlands receiving mine drainage

DISCUSSION

The preliminary data show the small number of species found in both natural and constructed wetlands receiving mine waters. In the US a total of 593 macrophyte plant species have been reported from constructed surface flow treatment wetlands and 427 from natural treatment wetlands (Knight et al. 2001). However the important difference is that this includes systems treating municipal waste waters which provide a very different chemical environment. Mine waters in contrast to municipal waters have a number of attributes that provide stress for plants. They can contain a number of different potentially phytotoxic metals at elevated concentrations, may be acidic in nature and usually have very low concentrations of essential nutrients such as phosphate and nitrate. Plants growing in uncontaminated wetlands are already subject to a number of stresses owing to the low oxygen conditions and fluctuating water levels. Thus, the additional stressed provided by mine waters may be enough to significantly reduce the number of species that are able to tolerate and adapt to these multi-stress environments.

The low number of species also raised some important fundamental questions regarding metal tolerance in plant species. Metal contaminated soils have been available for plant colonization for thousands of years and thus now support distinctive metallophyte floras (Baker 1987), but this is clearly not the case for wetlands. It is not evident to what extent the long history of metal contamination is equally true for wetlands and therefore it is possible that a lack of distinct floras is due to a shortage of time for evolution. However evolution of metal tolerance has been shown to be a rapid process in many cases and can occur within one generation provided appropriate genetic variability is available (Bradshaw 1984). Genetic variation has also been shown to be important in the adaptation strategy of terrestrial tree populations to pollution stress (Prus-Glowacki *et al* 1999). This suggests that it is possibly a lack of sufficient genetic variability within wetland plant species that has prevented the diversification of tolerant species but this requires further investigation. Recent work has suggested that wetland plants may have a constitutive metal tolerance without previous exposure to metals (Matthews *et al* 2004), but the lack of species diversity found in the present study indicate that this may not be the case. This should become more apparent with further collection of data.

The species composition differed between natural and constructed wetlands. There was no obvious environmental reason for these differences (e.g. water depth, pH etc) but further work will be undertaken to investigate this pattern further. However, the number of new species that could be used within constructed wetlands was very small. If there is a limited number of species that are able to tolerate the stresses of mine water pollution then it may not be possible to increase the plant biodiversity of treatment wetlands. However the macrophyte community only constitutes part of the overall ecosystem. One of the key groups within wetlands is the macroinvertebrates as they have an intrinsic role in linking the physico chemical environment and higher taxa. Therefore they provide a good indicator of the capability of wetlands to support a diverse faunal community. Research has shown that constructed wetlands are able to support a diverse macro invertebrate community (Batty *et al* 2005). The diversity of the community was strongly linked to water quality and therefore the ability of wetlands to support diverse faunal and floral communities may be restricted to areas where metal concentrations are much lower. This occurs in polishing wetlands and in distal regions of systems. In order to decrease the metal concentration to very low levels from minewaters passively it is necessary to have a comparatively large area of wetland and could therefore provide an opportunity to maximise the ecological potential. However further investigations into the complex relationships between species and the environment within contaminated wetlands need to be carried out.

With further understanding of the controls on ecological communities within wetlands it may be possible to make engineering or management decisions to maximise the ecological potential. It is important that this does not compromise the removal efficiency of the systems, but existing wetlands show that removal can be ensured while concurrently supporting the basis of communities (Batty et al 2005). This can be carried out in conjunction with similar restoration of surrounding terrestrial environments within the mine site. Areas within the site can be set aside to support the ecologically important metal tolerant communities which are threatened where they naturally occur. Abandoned mine sites have also been shown to support other orders such as mammals (e.g. Lacki *et al* 1991; Lopez-Gonzalez & Torres-Morales 2004), amphibians (Lacki *et al* 1992) and terrestrial invertebrates (Brändle *et al* 2000, Barnatt & Penny 2004). It is important that the potential of mine sites to support these organisms should be considered when restoration and closure plans are prepared.

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