

RECENT DEVELOPMENTS IN THE USE OF MINING AND OTHER WASTES IN LAND
RECLAMATION IN THE UNITED KINGDOM¹

Peter J. Norton
Research & Development Manager
British Coal Minestone Services
Philadelphia, Houghton-le-Spring, Tyne and Wear. DH4 4TG
United Kingdom

Abstract.--Subsequent to recent reorganization, British Coal Corporation's Minestone Services have embarked on a considerable research programme directed towards the use of colliery waste and other problematic waste products in the reclamation of derelict land. In this manner a dual environmental benefit is gained by, on the one hand clearing up abandoned pit heaps and on the other using the material to clear up other derelict areas, whilst at the same time saving other strategic bulk-fill materials which might otherwise have been used. Until recently use of minestone as a soil in land reclamation to lowgrade agriculture has been limited because the material is low in plant growth nutrients. In the past, large and expensive amounts of fertilizers and topsoil were used to achieve successful growth which often required later further applications to prevent regression. Now, with the use of colliery waste, which physically forms a good basis for soil, and other waste materials such as sewage sludge, pelletized refuse, and flue gas desulphurization end products from coal-fired power stations, it is hoped that restoration can be made very cheap and effective. Because these materials also pose acute disposal problems, their combined use as soilmaking material can often be achieved for haulage costs alone. Where amenity use restoration is concerned it is often desirable from a planning regulation point of view to restore sites to acceptable and aesthetic levels using trees. The recent developments in biotechnical engineering have advanced the possibility for much improved success rates in tree planting using mycorrhizal inoculants. This method is now being researched to perfect transplantation of the more sought after trees such as oak, beech, and ash. A second area of research using colliery wastes and other waste materials is in restoring mine sites to amenity lakes or wetland. Wet restoration has always been a problem for mining companies where a high ground water table exists and there is the possibility of acid mine water in the restored lake. Recent developments in the use of sewage sludge through the process of eutrophication have made it possible to

not only restore mine sites to acceptable lake amenity use, but also to use problematic colliery waste as bulk fill to prepare the geometry of the lakebed in other mines and quarries. With the additional use of wetland environments to create an environmental 'niche' for wildlife many old mining sites can now be confidently restored very cheaply to publicly acceptable use.

INTRODUCTION

Since 1987 is 'European Year of the Environment' (EYE), it is significant that a number of new laws and regulations have been introduced by the Department of the Environment in the United Kingdom that specifically relate to the disposal of mining waste (Dept. of Environment 1987). As recently as 1984 the Survey of Derelict Land in England showed that there were over 45,000 ha of derelict land which were classified as justifying restoration. Of this, by far the largest proportion (29%) was associated with coal mining. There were also about 40,000 ha of derelict land in inner city environments which also required urgent attention and have given rise to the formation of Urban Development Corporations in the worst areas of urban decay.

During the last decade British Coal

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has undertaken considerable research work into methods of assisting in the removal of these environmental eyesores. Many of the streams and lakes in coal mining areas suffered from the effects of acid mine drainage and only in recent years have steps been taken to alleviate this problem in order to meet the strict controls under the Control of Pollution (Rivers) Act 1974. The success met with in this endeavour and in cleaning up other forms of river pollution has resulted in a recent survey (Water Research Centre 1987) showing that the United Kingdom now has the cleanest river system in Europe (table 1).

Although as table 1 testifies, much has been done in the United Kingdom to purify rivers and lakes, there are still many areas of dereliction caused by industries that have long since been abandoned which require reclamation.

Table 1.--Pollution in European Rivers
(Water Research Centre 1987).

Country and date of survey	Proportion of river length in UK quality classes (%)				
	1A	1B	2	3	4
Belgium (75-9)	35	21	17	16	11
Denmark (86) (est)	(----80----)(---20----)				
France (81)	8	26	60	6	
West Germany (85)	6.5	38	40	14	1.5
Greece (est)	20	40	20	15	5
Ireland (80/1)	(---84---)(---14---)(-2-)				
Italy (no survey)	-	-	-	-	-
Luxembourg (84)	47	25	13	11	4
Netherlands (78)	12	65	18	4	1
UK:					
Eng & Wales (80)	36	33	21	8	2
Scotland (80)	95		4	0.5	0.5
N Ireland (85)	15	69	11	5	0
EEC Overall	14	25	35	22	4

There are over 1,000 Million tonnes of coal mining waste disposed of above ground level in the United Kingdom, the legacy of over 500 years of continuous mining. Modern high-production long-wall coal mining methods are also extremely wasteful, and this figure is being added to by about 60 Million tonnes every year.

There is therefore considerable logic in not only restoring existing areas of coal mining wastes, but also in using these considerable reserves of material as bulk fill in the restoration of other derelict areas. One of the major problems in the past has been difficulty in using the top layer for growing plants in agricultural or amenity use. This often necessitated the use of considerable amounts of expensive topsoil, chemicals, and fertilizer.

Where a good cover of grass or trees is required on land reclaimed with colliery waste, then the use of variable mixes of other waste products such as sewage sludge, flue gas desulphurization end-products, and pelletized refuse from urban incinerators can have a beneficial effect.

More than often local government planning regulations insist on the planting of trees to increase the aesthetic value of the restoration. The success rate of transplanted nursery trees can be greatly enhanced through the use of biotechnically engineered mycorrhizal inoculants of fungi on the roots during transplantation.

Many areas of dereliction are in tracts of land which are below the water table. This is especially true of abandoned surface mines and quarries. In order to restore these, bulk fill in the form of minestone can be used. However, if it is used, there remains the problem of potentially acid waters occurring in the subsequent lake or wetland environment. The use of selected sewage sludge in such environments has recently proved to be effective in maintaining a neutral pH. In this way the mines and quarries can be handed over as recreational areas for water sports or as wildlife reserves for waterfowl and other endangered species.

The prospect of such restoration often meets with considerable sympathy with government bodies when planning permission is sought for the original mining venture.

VEGETATION GROWTH ON COLLIERY AND OTHER WASTES

In the past in order to achieve good vegetation on colliery waste considerable amounts of chemicals and fertilizer had to be used to reduce the acidity and to provide nutrients for the plants. In order to create the necessary conditions for plant root growth the surface must be left uncompacted and open for moisture and air

to penetrate. These, of course, are the very conditions in which acidity is generated by the breakdown of iron pyrites (FeS_2) which can vary between 0.5% and 7.0% in British spoils. One gramme of sulphur will produce 3.06 g of sulphuric acid in the overall reaction which is accelerated in the presence of certain bacteria and is also exothermic. The resultant high temperatures also do little to promote moisture retention and root growth.

Using topsoil to cover the colliery waste is not practical because good topsoil is a rare commodity in many of the coal mining areas as a result of the downturn in large civil engineering projects during recent years. As a result of this, it is therefore very expensive, at around £3000/ha. It is thus of considerable benefit to be able to provide a growing medium without recourse to topsoil or large amounts of chemicals. Chemicals also leach out of the spoil very quickly, and repeated doses are required for many years in order to prevent regression of growth. Many restoration projects in the past have suffered this way and there is a need for a one-off treatment during restoration which will last until the plants have become established and self generating. Some other waste products offer this potential and often have disposal problems of their own which mean they are cheap and plentiful.

Sewage Sludge

A great deal of research is taking place into the use of sewage sludge in reclamation using colliery spoil. (Hall et al. 1986, Hall and Vigerust 1983). The main benefits of sewage sludge are that it gives up its nutrients slowly and has high moisture retention properties. It therefore has the advantage over chemicals in that it will allow a well-established vegetation to form without regression. Its main use is in the formation of poor grazing and amenity use land. The most important factor concerning its use is that the sewage sludge must be selected carefully. It has gained an unfortunate reputation with the public and some local authorities as a result of some cases where highly toxic forms of sewage have been used in the past. The improvements in sewage treatment in recent years and more restrictive legislation as to its use have now meant that it is used quite frequently in pit heap restoration and in final restoration in surface mining.

In some areas the sludge cannot be used as it contains heavy metals in excess of the Department of Environment (1984) guidelines on the disposal of sewage (table 2).

Several trials have now been undertaken by the Water Research Centre, various local water authorities, the Ministry of Agriculture, and British Coal and the results to date are extremely

encouraging. It is envisaged that it will be particularly useful in areas where top-soil is naturally scarce and in areas of industrial and urban dereliction.

Table 2.--Dept. of Environment guidelines for some toxic metal 'trigger' concentrations (in mg/kg).

Zootoxic Metals	Agricultural	Amenity
As	10	40
Cd	3	15
Cr	600	1000
Pb	500	2000
Mg	1	20
Sc	3	6

Use of sewage sludge in reclamation has an added benefit in that sewage sludge disposal is a major problem in a densely populated country such as the United Kingdom. In England about 30% is disposed of at sea and in some parts of the U.K., notably Scotland, as much as 78% is disposed of in this way. It is doubtful whether legislation, either local or by the European Parliament, will allow this to continue ad infinitum, and stricter controls are inevitable. At present only 7% is used in land reclamation, the remainder being used for agricultural purposes. There is much potential therefore for its use in land reclamation.

Biotechnical Engineering

Trees are probably the most important facet of any restoration and are certainly the form of vegetation cover which Planning Authorities would hope to see in any reclamation project. Trees which have been seen to thrive naturally on even acidic spoils have been found to have a symbiotic fungal growth on their roots. These ectomycorrhizae form a sheath which protects the tree from the aggressive environment, and fungal shoots (hyphae) extend the root system in search of the scarce nutrients in such a soil. Through advances in biotechnical engineering it is now practical to take a culture of the specific fungus appropriate to each species of tree and create a 'root dip' for use when the tree is transplanted from the nursery onto the reclaimed land. The success rate for tree growth is greatly improved at a cost of only around three pence per tree. In some recent experiments carried out for British Coal by Biotal Ltd. the success rate for Sitka Spruce using a mycorrhizal inoculant of *Laccaria laccata* gave shoot lengths of 25 cm after 36 weeks compared to untreated specimens of only 10 cm during the same period.

Biotechnical Engineering can also be used to develop plants which can thrive in

aggressive conditions. It is the intention of British Coal to promote the use of colliery waste in marine environments for such schemes as tidal barrages and dockland restoration. These areas are susceptible to salt spray, and it is hoped that biotechnical research will find plants that can withstand both the salt and acid soil environment.

Many of these applications are on steep slopes and the selection of certain plants such as the Black Locust tree, which has an 8-m-deep root system, can be used as a natural and more aesthetic form of slope stabilization than normal civil engineering methods. The roots of this tree act as natural soil anchorage systems and have a tensile strength of about 1,200 kg/cm² (Waldron 1977). It is hoped that these more natural forms of stabilization will be used more frequently in road and rail embankments, other slope construction, and even in surface mine design.

WET RESTORATION USING COLLIERY WASTE

Many derelict land sites, surface mines, and quarries are in areas where there is a naturally high ground water table at or near the surface (Norton 1983). Quarries which are excavated for bulk minerals are often abandoned with a large void which cannot, for one reason or another, be reclaimed with any locally available material or cannot be used for refuse disposal because of the high water table. However, the site can be reclaimed to a lake or wetland environment by partially filling the void using colliery waste which is in abundant supply and will usually only incur a haulage cost, as opposed to other bulk fill materials which have to be excavated from green field sites.

In the past mining waste has caused problems with acid mine water resulting from the oxidation of the ubiquitous iron pyrites. Until recently the only cure was to treat the water with lime or caustic soda. This was not only expensive and environmentally problematic, but also required frequent subsequent doses to prevent acidic regression. At one mine site about 50 tonnes of lime per week was necessary to treat an outflow of 160 L/sec with a pH of less than 4. The resultant annual cost was in the region of \$1 Million. Similar expensive methods have also been used in the treatment of acid lakes caused by sulphuric air pollution from coal-fired power stations.

The use of sewage sludge as an alternative treatment was first researched in the United Kingdom by the Freshwater Biological Association in conjunction with British Industrial Sands (Davison 1986, Needham 1986) at a sand quarry with a high water table which resulted in a lake with a pH of 3. Although the acidity was caused by the presence of iron-rich minerals in a bed of sand below the restored quarry floor, the principle of the remedial

measures is similar to that proposed at sites using colliery waste.

Minestone is a very suitable material for this purpose as its removal from existing pit heaps improves the environment and releases the land for development. The restoration of a site to amenity lake or wetland involves four distinct stages: backfilling, inundation, neutralization, and eutrophication.

It is essential that the backfilling creates a suitable geometry for the proposed lakebed with maximum angles of 14° and as much of the area horizontal as possible. Simple compaction with sheeps foot or vibrating rollers is then necessary to provide an impermeable top layer. Normal colliery waste can provide permeabilities as low as 10^{-8} cm/sec and is used to prevent the ingress of further acidic water.

The next stage is inundation, where all the dewatering mine pumps are switched off and the lake filled as quickly as possible. The diversion of other unpolluted surface waters into the lake can be used to speed up the process and also to dilute the acidity.

Once the lake is full then the remaining acidity in the water can be reduced further with a one-off small addition of lime or preferably caustic soda if, as is usual, the water is high in calcium salts. About 100 tonnes of caustic soda/10 million m^3 of water is all that is required if the pH is around 3.5.

In the final stage sewage sludge is added in order to provide organic material on which anaerobic bacteria feed and convert sulphates in the polluted water to sulphides by a process known as eutrophication in a reducing environment. It is essential of course that the lower levels of the water are still and any potential turbidity caused by flood conditions can be prevented by the construction of a weir system upstream of the lake. The deepest part of the lake is therefore kept anoxic, allowing the bacteria to thrive. Eventually the lakebed is composed of organic sediment and layers of harmless metallic sulphides as occur quite naturally in deep stagnant lakes (Love 1967). One of the main criticisms of this method is that some sewage contains pathogen and toxic metals. It is therefore important that the correct type is used. Modern methods of sewage treatment can now provide the necessary material. In addition, the fact that the water is acid usually eliminates any pathogens that remain.

The construction of a wetland or bog environment on the site can be used to treat the acidity that may be generated from colliery spoil outside the catchment of the lake. These wetlands have the added benefit of providing an ecological 'niche' for wildlife which creates much public and

planning approval and also prevents pollution of downstream watercourses.

CONCLUSIONS

A combination of any of the above methods of restoration have now given an added impetus to the potential use of colliery waste in the reclamation of derelict land and quarries and its use in marine and land-based structures. The combined use of waste materials and the modern science of biotechnical engineering can do much to improve the environment in coal mining areas. The dual benefit of simultaneously removing abandoned pit heaps and using the material for reclaiming other areas of dereliction cannot now be ignored, and with local and national government support it is hoped that much more use can be made of this readily available and increasingly valuable source of bulk fill material.

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