RESTORATION OF PYRITIC COLLIERY WASTE WITH SEWAGE SLUDGE IN THE MIDLANDS COALFIELD, ENGLAND, UNITED KINGDOM[1]

R. Neil Humphries[2], Gordon E. McQuire[3] and Martin Sly[4]

Abstract: A trial was set up in 1990 in the Midlands coalfield in the United Kingdom (UK) to evaluate the use of sewage sludge to revegetate colliery waste tips containing 1 - 2% sulfur as iron pyrites.

The rate of sewage sludge application is currently restricted by legislation and codes of practice to maximum concentrations of potentially toxic elements (copper, nickel, zinc, etc.) in the soil or waste after application. Following this guidance, an application rate of 250 mt/ha dry solids was applied at the trial site. At this rate, the colliery waste became extremely acidic pH <4.0. From experience elsewhere, much higher levels have been found to be necessary to control acidification in the absence of other measures or treatments.

In view of the restriction on the amount of sewage sludge that can be applied, it is recommended that the current practice of covering fresh colliery wastes with soil or low sulfur spoil to a minimum depth of 0.45m is continued in the UK. Where this is not possible, the sludge must always be applied with sufficient neutralising agent to control the potential acidity. If the acidity cannot be maintained above pH 5.0, the guidelines do not permit the application of sewage sludge.

Additional Key Words: pyritic wastes, acidity, sewage sludge, soil cover.

Pyritic Colliery Waste in the UK Coalfields

Current coarse washery discard colliery wastes in the UK average between 0.2% and 2.0% sulfur in the form of iron pyrites (Glover 1984), although locally much higher levels are frequently recorded in the more pyritic wastes. The most pyritic wastes occur in the Midland coalfields of Nottinghamshire and Yorkshire and in the western Scottish coalfield. Modern waste tips are formed using earth-moving plant which, through compaction, has largely eliminated the risk of spontaneous combustion and reduced the oxidation of pyrite within the tip. There remains the potential for acid generation in the final surface layers, which generally are required to be uncompacted and permeable for the purpose of revegetation.

While the modern construction methods for waste tips have much reduced the risk of acid mine drainage, there is still concern about surface acidification and subsequent pollution of watercourses and bodies by acidic runoff containing soluble salts and metals. Also, surface acidification can be of significance for restoration by causing poor vegetation growth and, in extreme cases, loss of vegetation. Both conditions can be time consuming and costly to rectify. Therefore, the prevention and treatment of acid potential and acidity has been, and continues to be, a priority in modern colliery waste restoration in the UK.

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[2]R. Neil Humphries, Technical Director, Humphries Rowell Associates, Loughborough, UK.

[3]Gordon E. McQuire, Chief Civil Engineer, British Coal Corporation, Eastwood, Nottinghamshire, UK.

[4]Martin Sly, Head of Tips and Restoration, British Coal Corporation, Midlands Group, Edwinstowe, Nottinghamshire, UK.

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Practices for Treatment of Acidity

Use of Neutralizing Agents

Traditionally, the method to control acid generation and to treat existing acidity in the surface layer of colliery waste has been to apply neutralizing agents, such as limestone ($CaCO_3$) or lime (CaO), as used in the management of agricultural soils (ADAS 1981).

Where the potential for acid generation is low (i.e., on "average" pyritic sulfur <0.5%S) and where existing acidity has not been extreme (i.e., pH >/= 4.5), the traditional method has generally been successful for colliery waste when the recommended practices for application and incorporation have been properly implemented (Rowell and Humphries 1985).

However, the approach has not been consistently effective where the potential for acid generation is moderate to high (i.e., >1.0%S), and/or where extreme acidity exists (i.e., pH <3.5). This is due to the very high quantities of neutralizing agent needed and often the need for repeated annual applications (Simmons 1984, Backes et al. 1985, Rowell and Humphries 1985). Both can cause severe practical difficulties during application and incorporation, and have been a source of public nuisance owing to windblown material during application, besides inducing problems for vegetation growth. In addition this approach is often costly to implement.

Use of Soil Cover

Since the 1970's planning consents granted by the local government mineral planning authorities have normally contained a condition that requires new, and extensions to existing, colliery waste tips to be covered with a layer of soil or "soil-forming materials" (Humphries 1984).

Where soil material is available, this method has provided a means whereby the rate of acid generation can be more effectively controlled. The effectiveness is related to the depth and type of soil cover and the degree of pyrite oxidation prior to covering. The control of acidification appears to have been successful where a soil cover in excess of about 0.5 m has been applied (although no systematic field assessment appears to have been undertaken). Shallower depths of cover, and in particular soil cover of less than 0.2 to 0.3 m, does not prevent acidification of the underlying waste (Rowell and Humphries 1985). However, the application of a cover of soil has proved to be generally beneficial for vegetation, even where the waste has acidified beneath a shallow cover. Depending on depth of cover, it has been possible to establish a range of vegetation types and land uses (Humphries and McQuire 1994), which can be managed by normal agricultural, forestry, and wildlife practices.

Alternative Methods of Control and Treatment of Acidity

In the past soils were not stripped before tipping colliery spoil, and many older tips in the UK have little or no soil material to cover the final surface (Humphries 1984). Because of this, there has been considerable interest in alternative methods of controlling pyrite oxidation and acidity (Macpherson 1987, Metcalfe and Lavin 1991, Pulford 1991a/b). Also, because of economic pressure to reduce waste disposal costs, there has been recent interest in the coal mining industry in the use of organic wastes, either instead of spreading a soil layer or in conjunction with a shallower layer of soil over the colliery waste.

There is evidence from laboratory studies that the oxidation of pyrite can be inhibited by organic waste materials such as manures (Backes et al. 1987). Furthermore, the work by the water utility Yorkshire Water Ltd. has shown that acidic colliery waste can be effectively revegetated using treated human sewage effluent (Metcalfe and Lavin 1991).

The practice of applying sludge to agricultural land, mineral wastes, and derelict land has a long and successful history in the UK, where it has been carried out in a controlled manner and according to recommended practice.

Currently, about 5% of the 1 million mt dry solids of sewage sludge produced annually is used in land reclamation (Hall 1988). With an ever-increasing requirement for the utilities to dispose of sewage sludge in an environmentally safe and economic way, they see its use in colliery waste reclamation schemes as a major opportunity for disposal (Severn Trent Water 1990).

Trial Use of Sewage Sludge

Introduction

In 1990, Nottinghamshire Group (now the Midlands Group) of the British Coal Corporation and the water utility Severn Trent Water Ltd. set up a long-term trial to evaluate the use of sewage sludge to revegetate colliery waste tips as they are completed. Humphries Rowell Associates (HRA) was contracted in 1992 to monitor the trial at Thoresby Colliery for a 5 yr period.

The trial comprises some 31 plots of various treatments. These include soil or soil-forming material (sand) spread to a depth of about 0.6 to 0.7 m over untreated waste, a mixture of sand and waste to a depth of 0.5 m, and colliery waste only. The trial includes these treatments with and without the addition of undigested sewage sludge as de-watered cake at 250 mt/ha of dry solids. The sewage sludge was applied in November 1990, and was incorporated to a depth of about 0.3 m using both tines and a "spading" machine, generally resulting in a uniform mixture of waste and sludge. The plots have been either sown with a ryegrass (*Lolium perenne*) - white clover (*Trifolium repens*) pasture mixture or planted with tree species (mainly silver birch (*Betula pendula*), sessile oak (*Quercus petraea*) and Scot's pine (*Pinus sylvestris*)). The plots with a 0.6 to 0.7 m layer of soil or soil-forming material represent the current restoration treatment practised by the Group.

Various chemical data (nutrients, metals, etc.) for the "soil layer" for the period 1990-91 were collected by British Coal; thereafter HRA collected both soil and vegetation for analysis and recorded vegetation growth and development.

Results After 4 Yrs

The colliery waste plots without a soil cover show the typical rapid decline in pH from the saline fresh waste to an extremely acid waste resulting from pyrite oxidation over some 4 yrs (table 1). The addition of the sewage sludge to the waste at the permitted rates did not inhibit the development of acidity. In contrast, the "soil layer" of the soil-covered plots, with or without sludge treatment, did not become acidified (table 2).

Despite the generation of acidity within the colliery waste plots treated with sewage sludge, the ground cover vegetation has largely persisted, although at a lower level of cover than the soil- and sand-covered plots. Also, the growth of birch in 1993 on these plots was comparable to that on the plots with a cover of soil or sand (table 3). In contrast, the untreated shale plots had almost no ground cover vegetation and the few surviving trees generally exhibited "dieback" and a greater proportion of trees without expanded leaves.

Table 1. Development of acidity in untreated and sewage sludge treated waste, pH.

	1990	1991	1992	1993
Untreated colliery waste	8.3	NA[1]	3.1	2.9
Treated with sewage sludge	8.3	6.6	4.9	3.5

[1]NA = Not available.

Table 2. Soil reaction (pH) of plots in 1993.

	Waste	Waste and sludge	Sand layer	Sand layer and sludge	Soil layer	Soil layer and sludge
pH....	2.9	3.5	5.6	6.2	5.9	6.6

Table 3. Growth of birch and herbaceous ground cover on plots in 1993.

	Waste	Waste and sludge	Sand layer	Sand layer and sludge	Soil layer	Soil layer and sludge
Mean increase in birch height (cm)........................	-23[1]	22	10	19	25	33
Mean increase in birch spread (cm).......................	-5[1]	33	16	23	32	33
Percentage trees alive.........	4	74	68	63	65	52
Percentage herbaceous ground cover.....................	3	40	80	95	80	100

[1]Represents net dieback.

Discussion

The ability of organic matter to control the oxidation of pyritic spoil has been demonstrated and is well understood (Backes et al.1987, Pulford 1991a). The failure of the sewage sludge to inhibit acidification of the pyritic colliery waste in the trial is however in accordance with experience elsewhere in the UK and in the United States, where low rates of sludge have been applied (Metcalfe, personal communication). Much higher rates, such as 750 mt/ha dry solids, appear to be necessary to control acidity.

Backes et al. (1987) suggested that the inhibition of pyrite oxidation by organic manures may be dependent on a close contact between the pyrite and the organic matter. As a good degree of mixing had been achieved in the trial, the failure can only be reasonably attributed to the low rate of application.

The rate of sewage sludge applied in the trial had been determined by the supplying utility, Severn Trent Water, which complied with current UK recommended practice and legislation designed to prevent the buildup and mobilization of potentially toxic elements (copper, nickel, zinc, etc.). The rate was limited to the maximum currently permitted for agricultural land (Department of the Environment 1992), which is the same as that recommended by the Forestry Commission and Water Research Centre (Wolstenholme et al. 1992) for woodland and public open space. Hence under current guidelines, the use of higher rates of sewage sludge necessary to control acidity at the site would not have been permitted. Furthermore, Wolstenholme et al. (1992) recommended that the maximum application rates for restoration should be restricted to 100 mt/ha dry solids.

The draft guidance issued by the Water Research Council (Hall 1988) advises that sewage sludge should not be relied upon to control acidity where the soil layer has the potential to become acidic as in the case of colliery waste. In these cases they recommend that the material should be suitably limed. Unfortunately, this advice was not included in the operational guidelines published subsequently by Severn Trent Water (1990) and implemented at Thoresby.

While the same restrictions apply to soils and soil-covered wastes, there is generally little risk of acidification and therefore generally no need for additional lime treatments or higher rates of sludge application. Hence, from both an operational point of view and one of least risk, sewage sludge application is best restricted to soil covered wastes.

Where this is not possible, it is essential that sufficient neutralizing agent (e.g., limestone) is applied to treat the potential acidity.

Guidelines for Restoration of Pyritic Colliery Wastes

For reasons of minimizing pollution and achieving successful and cost-effective restoration, the control of acidification must remain a priority for restoration of colliery waste tips in the UK.

The most effective means of controlling acidification is to cover pyritic wastes with soil material. It is recommended that the current British Coal best practice of immediately covering fresh mine waste with soil material to a minimum depth of 0.45 m (or greater depending on proposed land use) be continued. Where soil is not available, a cover of low pyritic material, which may be colliery waste, should be spread over the final layer of pyritic material to a depth of 0.45 m. Where the cover is less than 0.45 m, the current practice of adding neutralizing agents, such as limestone, to the underlying waste should be continued according to the scheme shown table 4.

Wherever sewage sludge is applied in the UK, the rates of application should accord with the current guidelines and codes of practice. These are published by the Department of the Environment (1992) for agricultural soils, and the Forestry Commission (Wolstenholme et al. 1992) for forestry and public open space. At these rates, sewage sludge is unlikely to control acidification in pyritic wastes. In the absence of soil material, sewage sludge should always be applied with neutralizing agents following the recommendations given in table 4. If there is any uncertainty about the control and maintenance of acidity above pH 5.0, sewage sludge must not be applied.

Table 4. Recommended treatment strategy for pyritic wastes.

	Soil cover			
Pyritic sulfur (%S)	<150 mm	150 to 300 mm	300 to 450 mm	>450 mm
<0.5........................	CLD[1] to 300 mm	CLD to 300 mm	½ CLD to 150 mm	Nil
0.5 to 5..................	CLD + 20 mt/ha per % S to 300 mm	CLD + 20 mt/ha per % S to 300 mm	½ CLD + 10 mt/ha per % S to 150 mm	Nil
>5...........................	Cover with 450 mm of low pyritic spoil <5% S and treat as above			

[1]CLD = Calculated lime demand using ADAS (1981) methodology. If limestone addition rates > 20 mt/ha, use only calcitic limestone.

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