Two Decades of Mine Reclamation: Lessons Learned from One of the Nation's Largest Biosolids Beneficial Use Programs

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Abstract

Pennsylvania has been a leader in the use of biosolids for reclamation of mine lands. Federal mining laws established standards for reclamation, and marine protection legislation banned the practice of ocean disposal of biosolids. As a happy confluence of needs, biosolids from Philadelphia were made part of the early development of approaches in Pennsylvania for compliance with mine reclamation requirements.

This paper is a retrospective of lessons learned from the Pennsylvania program. Over a two-decade period, the field experience with biosolids use continues to demonstrate clear environmental benefits and negligible adverse effects. Re-inspection of sites, even two decades after completion, shows vigorous ground cover, signs of active animal populations, minimal surface erosion, and clear flowing waters in nearby watercourses.

This paper summarizes the aspects of this program which allow it to be a model for biosolids recycling programs in other states and regions, and it will present priorities for additional study to address areas of technical and public concern.

Background

History of Mining Reclamation

Practices of modern mine reclamation and biosolids recycling emerged coterminously in the mid 1970s. The federal Surface Mine Reclamation Act of 1977 required mine reclamation. And under the Marine Protection, Research and Sanctuaries Act of 1972, the US EPA had compelled the City of Philadelphia to abandon its ocean dumping of solids in favor of land application. These two programs came together in the late 1970s as experiments in mine reclamation with biosolids.

Pennsylvania has been a leader in the use of biosolids for reclamation of mine lands since the 1970s. Research by Penn State professor William Sopper, undertaken in the 1970s and early 1980s, remains preeminent for its documentation of the environmental effects of biosolids use in land reclamation. Yet reclamation work did not end with the research, and Philadelphia has been since joined by other municipalities in the employment of biosolids at mine closure sites in Pennsylvania. The program for reclamation has now completed twenty years, amassing a track

record of over 4,500 acres reclaimed and the utilization of more than 750,000 tons of biosolids products.

Federal mining laws were an impetus to this program. Reclamation of mine sites, and the posting of bonding by coal mine companies to guarantee reclamation, had been always required. But the size of the bonds and the details of their release to the coal companies increased after 1977. The release of bonds became a three-stage process. Stage 1, the rough grade of the site with backfill, allowed release of 60% of the bond; Stage 2, planting of ground cover, released another 25% of the bond; and, Stage 3, the remaining 15% of the bond, required 5 years for full performance. Coal companies frequently experienced difficulty meeting the Stage 3 standards, and remedial plantings were frequently necessary. The immediate payback of reclamation work at mine sites using biosolids was in the near certainty that Stage 3 bonds would be released on schedule.

Pennsylvania, like many other states with coal mining activity, confronts an overwhelming challenge in stewardship of lands affected by extraction activities. An estimated 133,000 acres of mine lands pre-dating the 1977 law remain inadequately stabilized and could benefit from regrading and revegetation. Each year, an average of 12,000 acres of lands is disturbed by new mining activities. Although 40,000 tons of biosolids applied annually, on average, to mine lands in Pennsylvania between 1988 and 1997 is a substantial volume, this quantity nevertheless treated a scant 1.5 percent of lands disturbed by mining. In reflecting on the loss of soil and habitat resources as a consequence of mining, the genuine environmental issue ought not be how to better regulate use of biosolids in land reclamation, but instead how to ensure the greatest possible volume of biosolids is applied to mined lands.

To appreciate the scope of reclamation work and the role of biosolids, a description of the process of bituminous coal mining is useful.

Operators first remove the top stratum, called topsoil, but in reality a very shallow layer of unconsolidated rubble and soil particles. Then the operators remove the overburden, which is the rock layers overlying the coal. The rule is that as much as 20 feet of overburden can be economically removed for each one (1) foot of coal seam sought. The overburden is blasted with the sadly infamous ammonium nitrate/fuel oil (ANFO) mix. Operators pile the overburden off to the side of the excavation, keeping it handy for replacement. After the coal seam or seams are extracted, the overburden is replaced, shaping the surface of the overburden to approximately the original contour.

Runoff control is a part of the mining work. Sediment ditches and ponds are used to collect sediments from storm runoff prior to discharge of runoff to surface waters. These structures are kept intact until the end of stage 2.

Biosolids is part of achieving stage 2 bond release. After the overburden is put back in place, the “topsoil” is placed over the top of the overburden and smoothed out. Biosolids is spread over the topsoil, using farm type equipment. If anaerobic digested biosolids is employed (as in the case of Philadelphia’s biosolids), pulverized agricultural lime is applied at a rate based on a calcium carbonate equivalency calculation. Lime stabilized biosolids may not need supplemental lime amendment. The goal is to achieve a lasting soil pH of greater than 6.0. A common lime application rate may be as high as 6 tons per acre.

Techniques of Biosolids Applications

Biosolids Delivery and Staging

Biosolids are trucked to the mine site in triaxle dump trucks, which is a vehicle type commonly and economically available to the coal industry. Biosolids are emptied into a staging area, a bermed area made of overburden type material. If the biosolids are scheduled to be held for more than 30 days, a situation regarded as long term storage, the staging area is equipped with a leachate collection system, commonly a tarp-lined sump.

Biosolids Application and Incorporation

Any farm tractor and spreader equipment may be used to apply biosolids to the mine surface. The application rate in Pennsylvania has been typically 60 dry tons per acre. At the solids concentration of Philadelphia cake, this is approximately 250 tons per acre, and is a layer of biosolids about 2.5 inches deep. Biosolids may be applied in flat areas in one pass, but on hillsides several passes may be required. Biosolids are incorporated with chisel plow, with at least three passes, occasionally more, but with the last pass of the plow pulled along the contour.

Vegetation Establishment

Good vegetative cover establishment is the key objective of the reclamation work. A drill seeder is used to sow typically a blend of legumes and grasses. The landowner, who is generally not the coal mine operator, is involved in choosing the final vegetative land cover. The most common final use for the site is for wildlife habitat. Over the past several years, the variety of choices in vegetative cover have expanded, and warm season grasses, oats and buckwheat have been tried for their desirability for target game species.

If the revegetation plan calls for forest cover, the reclamation operator will cover 40 inches of the seeder drill to eliminate seeding in a strip left for planting seedlings. Trees are planted in early spring the year following the planting of grasses. Tree seedlings grow vigorously, although they have difficulty competing with grasses and surviving deer browsing.

Post Reclamation Requirements

Soil pH

Soil pH is checked annually in the fall to assure compliance with the pH 6.0 standard for at least two consecutive years following reclamation. Use of biosolids on reclamation sites, in conjunction with a liberal lime application, most often results in compliance with the standard. At conventional mine reclamation sites (sites in which chemical fertilizers and lime are used for soil preparation), re-liming in spring frequently proves necessary, and monitoring often continues for four years after reclamation before the standard is met on some sites.

Water Monitoring

Quarterly water monitoring continues for two years beyond completion of the soil pH goal (two years over pH 6). A state hydrogeologist selects monitoring points that are hydrologically connected to the mine. These points may be seeps, springs, streams or wells (even private wells). The mine operator is responsible for arranging the analysis of the samples and reporting the results to the mining officials.

Surface Vegetation

Surface vegetation must achieve coverage of 70% of the soil surface. The standard for Stage 2 bond release is 70% vegetative coverage. Stage 3 is accomplished when after 5 years the site still has 70% vegetative cover or better. The success of biosolids in reclamation is most marked in contrast to conventional techniques in the number of mines successfully meeting Stage 3 vegetative cover standards at the fifth year.

Surface Stability

Reclamation sites must exhibit surface stability, as defined by absence of gullies and by good vegetative cover, for Stage 2 and 3 bond release. Gullies are a common occurrence at reclamation sites treated with conventional reclamation techniques. Biosolids sites are typically free of gullies and usually exhibit no significant runoff during even very intense storm events.

Overview of the Biosolids Sites in Pennsylvania

The current state program for administering mining and reclamation activities was put into place in 1989. Since that time, 1,750 acres of mine lands have been reclaimed with 432,000 tons of biosolids products. Most of the mine reclamation sites employing biosolids have been within the bituminous coal mining region of northcentral Pennsylvania, a region whose mining activities are administered by the Hawk Run District Mining Office of the Pennsylvania Department of Environmental Protection (PaDEP). While Philadelphia has been the longest standing source of biosolids for reclamation work, two other sources from other Pennsylvania utilities are currently employed, and several sources have been from out-of-state. Virtually all sites are privately owned and are designated for wildlife habitat.

Permitting and Regulation

Biosolids are authorized for recycling under Pennsylvania's Municipal Waste Management Act. Biosolids regulations had been administered primarily by PaDEP's Bureau of Land Recycling and Waste Management. In January 1997, amendments to waste management regulations established a general permit program for biosolids recycling, and recent changes within the PaDEP have reassigned administration of biosolids regulations to its Bureau of Water Management.

But biosolids applications at mine sites are administered in a fashion different from other biosolids recycling activities. The new general permit program has granted to PaDEP's Bureau of Mining and Reclamation the authority to issue approvals for mine sites. Projects are reviewed and approved by that bureau's District Mining Operations, under an MOU with the Bureau of Land Recycling and Waste Management (an MOU with the Bureau of Water Management is pending). Biosolids use in mine reclamation is construed as a revision to the Surface Mine Permit issued by the district mining office. As part of that revision, public notice is required, and, when requested, the mining office will hold a public hearing.

Biosolids Impacts

Vegetative Establishment

Obtaining stage 2 and stage 3 bond release has been successful for coal mine operators in all cases in which biosolids have been used. Vegetation growth is vigorous at biosolids sites compared to conventional (chemically-fertilized) sites. The remaining, benign problem is that plant growth is so dense as to make difficult inspecting the sites in mid summer. The soil has substantial water holding capacity, a factor that helps enable plants withstand drought. Tomato seeds that come in with biosolids result in the added bonus of a tomato crop attractive to wildlife.

Wildlife Establishment

The bituminous coal mining area of northcentral Pennsylvania is a strong hunting region. The establishment of permanently improved wildlife habitat has helped develop public support for the program. This has been one of the very significant benefits of biosolids recycling. The choice of seeding and cover has been evolving over the past several years in response to game enthusiasts. For example, buckwheat generates wildlife that generates enthusiasm among the hunters.

Wildlife has responded enormously to the vegetative cover at the biosolids sites. A Pennsylvania District Forester was excited by the hold over of hawks at the edge of one reclamation site. The hawks are drawn to the mice and voles residing in the dense matting. A bald eagle was seen at one site and has been nesting for several years. Turkey flocks have grown large, as they are attracted to the fields due to dense grasshopper populations, and the turkey can readily retreat to nearby woods to roost. In 1998, reclamation sites will be sown to sorghum, using seed donated by the Wild Turkey Federation. Also, doves have flocked to these sites, attracted to the wheat, rye and oats that are a cover crop during the first year of reclamation.

Large-mammal populations have also increased. Deer frequent biosolids-amended reclamation sites. Deer are primarily woodland browser, but they come into the fields for buckwheat, and the fields appear to help offset variations in annual mast production within the forests. Nutrients in the browse on reclaimed mine sites seem to help build good racks. One exciting program developed by the Pennsylvania Game Commission is reintroduction of elk. An elk herd is being relocated to some large field reclaimed with biosolids and planted to warm weather grasses. The elk graze on the grass, and hence are not in competition with the deer. Anecdotal reports of bobcat sightings add to reported sightings of bear and fox at biosolids sites.

Erosion Control

Biosolids virtually eliminates erosion at reclamation sites. One factor is the deep chisel plowing undertaken during biosolids incorporation. The second factor is the root mass that develops under the grasses and legumes. Furrows created during biosolids act as small diversions. Even two-inch rainfalls have not shown surface runoff. Moisture retention is an added benefit of the control of surface runoff and erosion.

Low erosion at biosolids-amended sites is in strong contrast to conventional reclamation treatment that does not employ chisel plowing. Rills and gullies typically arise in conventional sites, and these become a continual maintenance problem. Bonds will not be released if rills exceed 9 inches in depth.

Water Quality Benefits

Acid Mine Drainage Control

No comprehensive study has been yet made of the changes to acid mine drainage (AMD) that result from biosolids use in reclamation. Quarterly monitoring data collected over the past decade yield a strong suggestion that AMD is significantly reduced from sites at which biosolids has been used. At one site, for example, seep discharges went from 0 units of alkalinity and 219 units of acidity to a remarkable net balance of acidity and alkalinity. A long time trend has not been closely examined, nor has the data been reviewed for all sites. A study of this phenomenon, complete with control sites, is warranted.

Nitrogen

No significant release of nitrogen to water monitoring points has been observed. The only exception is samples taken after heavy rainfall soon after biosolids applications. Nitrate levels fall quickly to background. Total nitrogen in a 60 dry tons per acre rate is about 2,500 pounds per acre, of which only about 5% is in the nitrate form and 15% is in the ammonium form. Eighty percent of nitrogen is in the organic form.

Phosphorus

No water monitoring samples have yielded phosphorus concentrations above background. This is a notable finding, as the application rate of total phosphorus is in the 3,000 to 5,000 pounds per acre range. As the biosolids industry begins to confront regulation of phosphorus, water quality data from reclamation sites deserve to be closely examined.

Metals Movement

Metals are not released in significant quantities from the completed reclamation site. This is based on research work performed in the 1980s as well as ongoing monitoring. In water monitoring data reviewed over the past several years, a pattern is seen of elevated metals in the initial samples after application, with concentrations quickly falling to background.

Public Awareness Issues

Early Program

Use of biosolids in mine reclamation faced serious public and political opposition in the early years. One controversy arose from reclamation done without public notice. Operational issues also contributed to early controversies, such as unconfined storage of biosolids close to streams and excessive application rates. Poor application practices were observed, such as inconsistent rates over a field and inadequate incorporation. A large political controversy ensued that resulted in banning of biosolids from counties and townships hosting the original application sites. Biosolids are still excluded from some of these localities.

Sproul Forest Debacle

Sproul Forest, a forest within the Pennsylvania state forest system, suffered an intense fire in 1991. To assist with remediation of this project, an experimental biosolids project was undertaken. Philadelphia delivered to Sproul Forest a biosolids material that was mixed with common fill as part of a clean up project at its facility. This mixed material was viewed later by the public as evidence of waste contamination of the biosolids. The community had not been notified prior to the project start up, because some regulatory procedures had been bypassed. Although results within the forest were good, significant public controversy was engendered by this project in the local press that has had long-term adverse effects on public acceptance.

Legislative Relations

An ongoing challenge to the mine reclamation program is engendering political support and managing political opposition to biosolids use. The state legislator representing much of the mining district frequently introduces legislation hostile to biosolids recycling. While his proposals would seriously affect biosolids program across the entire state, he has not typically sought to interfere with reclamation projects within his district. Elected township officials in recent years have not organized concerted opposition to biosolids projects, largely because neighbors to the site have not been objecting to the reclamation work. The lack of opposition is believed tied to the perceive value of wildlife habitat improvements. When issues arise, they seem to be spurred by odor emissions.

Watershed Management

As the national regulatory focus on water management has shifted to watersheds, the link between biosolids and water quality is beginning to be forged in Pennsylvania's mining region. Over the past decade, selection of biosolids application sites has focused on comprehensive improvement to the Tangascootack Creek Watershed, a watershed affected by acid mine drainage (AMD). Biosolids applications within this watershed seem to have served as a passive treatment system alternative for AMD control. Ten years of program activity within this watershed is demonstrating on a field trial scale that metals, sulfate and pH in seeps draining to the Tangascootack Creek have significantly improved following biosolids utilization.

This program demonstrating watershed benefits of biosolids use has evolved to include a wide number of groups. The watershed improvement program is connected to the Clinton County Conservation District, Pennsylvania Game Commission, the Pennsylvania Fish & Boating Commission, and the Pennsylvania Department of Natural Resources and Conservation's Bureau of Forestry.

Recommendations to Biosolids Managers

Form Partnerships

Utilities and applicators need to form partnership with their regulators. A regular refrain with the public is "who is watching this thing?" The public must know that someone with regulatory responsibility is monitoring the work. In programs where regulatory officials are involved, timely

decisions are made and programs are completed. The Pennsylvania mine reclamation program has enjoyed success in large part because of the commitment of mining officials to support biosolids use. They have consistently advocated biosolids for its genuine value as an ingredient in land reclamation and habitat restoration.

Send the Right Messages

The message has to be continually reaffirmed by both the regulator and regulated communities that biosolids are a resource for reclamation. Biosolids is not being "dumped," and all communications from the utilities and mining agencies need to reinforce this message. Unfortunately, because short dumping frequently occurs in old mine sites, the public naturally presumes that biosolids use is an example of further environmental abuse.

Use Demonstration Sites

Biosolids can be introduced to a reclamation program through small demonstration sites. This helps to develop believability within the community. If complemented with monitoring, the demonstration program can help characterize the performance of different biosolids (lime stabilized vs. digested vs. raw), varying application rates, and alternative seeding mixes.

Keep the Public Informed

All agents of the project, from utilities, to service companies, and to mining officials, must not fail to keep the public informed. Public officials need to extend to the citizens the opportunity to request and attend meetings, even though such meetings may not be fun. The industry needs to view such meetings as opportunities to show people the environmental benefits of biosolids use for reclamation and to help allay their concerns.

Demonstrate the Benefits

The biosolids industry has not been successful in the past at defining the payback of biosolids use. The industry needs to describe the benefits of recycling in terms of habitats, visual aesthetics and acid mine drainage.

Build a Constituency

A great opportunity presents itself in reclamation work with biosolids to build a constituency in favor of biosolids recycling. Governmental agencies responsible for game and forestry management and private organizations managing wildlife and hunting programs are natural allies, once the value of good reclamation has been demonstrated.

Employ Sound Site Management Practices

Biosolids applicators need to use good management practices in reclamation work. In addition to doing a good job of application and seeding, they need to be especially aware of off-site nuisances. They need to select truck routes that minimize intrusion in residential area, and they need to select their staging and temporary storage areas with an eye toward reducing odor complaints.

Temporary stockpiling is often helpful to make reclamation practicable. Reclamation sites require a substantial mass of biosolids to sustain a meaningful project. While large utilities are capable of providing this mass, small utilities have to stockpile biosolids to have enough to handle economically. The measure of sound stockpiling practice is containment on the reclamation site of all potential pollutants, whether in surface runoff, groundwater infiltration, or air emissions.

Some Remaining Issues

Application Rates

Pennsylvania officials long ago adopted a policy of permitting 60 dry tons of biosolids per acre for one-time application. But now that "agronomic rate" is part of the equation, this long-held

guideline is subject to change, and the behavior of nitrogen at the application sites may need to be reinvestigated. Research into the fate of nitrogen at reclamation sites is warranted. Experience in Pennsylvania suggests that even high biosolids application rates do not result in significant release of nitrogen.

Vegetation Selection

The type of vegetative cover planted at the sites is being reconsidered. The traditional grass-legume seed mix does not invite plant succession past open field habitat, and some experts have noted that efforts to restore forest habitat have not been successful. Alternative covers need to be tracked over long-term trials. Selection of plant types attractive to target game species is an avenue for further experimentation.

Acid Mine Drainage (AMD)

Some researchers have expressed concern that biosolids may aggravate AMD. They point to the lack of data on the field results of biosolids-based reclamation on acid mine drainage, and have hypothesized that high fertility may exacerbate acid formation. Field experience indicates that AMD is reduced with biosolids application. But the mechanisms by which this occurs are not known and deserve additional field-based research.

Temporary Stockpiling

Successful reclamation typically requires delivery of such substantial quantities of biosolids to an individual site as to warrant temporary winter-time stockpiling of biosolids. But state regulators are left with little national guidance as to how to control such activity. Evaluation of temporary stockpiling practices needs to be made to help provide background information for public officials responsible for developing standards and guidance.

Public Support

Even after a long and positive track record, the reclamation program remains a target of community and political opposition. An industry strategy for overcoming opposition and for building popular support needs to be developed and implemented. The focus of this strategy ought to be on describing the benefits of biosolids for wildlife habitat restoration.