Biosolids Use for Land Reclamation

SCHOOL OF PLANT AND ENVIRONMENTAL SCIENCES, VIRGINIA TECH

By: Odiney Alvarez-Campos and Gregory K. Evanylo

Background

Vast amounts of land are disturbed, contaminated, and incapable of supporting vegetation in the United States due to surface soil degradation through surface mining and improper handling and disposal of toxic materials and wastes (USEPA, 2007). More than 500,000 abandoned and inactive mine sites, which may have not been properly remediated and reclaimed after mining operations ceased, occur throughout the United States (USEPA, 2005). Many of these sites exhibit problems such as:Decrease bulk density (García-Orenes et al., 2005; Ouimet et al., 2015; Sloan et al., 2016)

- Toxicity of various soil contaminants, largely metals
- Soil pH values higher or lower than normal
- Excess salts (e.g. sulfates and chlorides) and sodium
- Disturbed soil physical properties (i.e. compaction, reduced aggregation, water infiltration, among others)

Such problems can limit soil fertility, plant growth and soil microbial community function, making it more difficult to reclaim and revegetate. Soil removal, containment technologies (i.e. vertical barriers to prevent movement of contaminants to groundwater), chemical treatment (i.e. lime use to neutralize acidity and precipitate metals), and application of soil amendments rich in organic matter are the most common approaches for rehabilitating such lands (USEPA, 2005). The use of organic-rich soil amendments is one of the most cost effective on-site remediation practices that can be used to restore degraded soil properties and revitalize disturbed contaminated sites (USEPA, 2007).

Biosolids benefits to disturbed lands

The use of residuals, largely municipal biosolids, has been successfully employed to restore disturbed soils (acid strip mines, coal refuse piles, etc.) for more than 25 years (Sopper, 1992; Haering et al., 2000; Brown et al., 2014). Biosolids amendments add organic matter and nutrients that improve soil physical properties and increase soil fertility of degraded lands (Nicholson et al., 2018; Brown et al., 2014; Basta, 2000; Lu et al., 2012). Biosolids alone or in mixtures with other amendments (e.g., lime, woody material, fly ash, saw dust) have also been used to correct specific problems (Brown and Chaney, 2000; Brown et al., 2014). Restoring soil properties also contributes to vigorous vegetative growth, which is vital to land reclamation (USEPA, 2007).

Many mine land reclamation projects have demonstrated the beneficial effects of biosolids application to restore soil properties and vegetation cover. Greater vegetation biomass increases were observed on biosolids-amended mine lands than on the same type of land amended with inorganic fertilizers (Sopper, 1992). The application of two dewatered biosolids (40 and 82 US tons/acre) to an abandoned strip mine land in Pennsylvania re-established complete vegetative cover of a mixture of two grasses (Kentucky tall fescue and Pennlate orchardgrass) and two legumes (Penngift crownvetch and Empire birdsfoot trefoil) within several weeks after biosolids application (Sopper and Kerr, 1980). Researchers noted that vegetative cover continued to improve even three growing seasons after biosolids application. Soil water holding capacity was increased and soil compaction was reduced after the combined applications of biosolids (200 US tons/acre) and limestone (20 US tons/acre) to an acidic coal refuse or gob pile in comparison to a control site that did not receive amendment application (Joost et al., 1987). Blended applications of 1/3 biosolids cake and 2/3 composted wood chips at high rates (82, 164, and 246 US tons/acre) gave greater forage biomass than inorganic fertilizer and unfertilized treatments in reclaimed coal mine lands of southwest Virginia after two growing seasons (Daniels and Haering, 1994). Brown et al. (2003) also observed that a mixture of biosolids with wood ash decreased subsoil acidity and extractable metals of an abandoned mine land in Idaho. The mixture of amendments helped restore plant cover in contaminated areas for 2 years after amendment application.

"Jump-starting" vegetative growth in such sites is important because vegetation can stabilize landscapes from further erosion, reduce surface water runoff and movement of water and contaminants to groundwater, and contribute to additional organic matter build up (USEPA, 2007). Such increases in soil organic matter can help sorb contaminants, which can reduce their availability by keeping contaminants in the soil's [unavailable] solid phase, rather than in the [available] solution phase (Chen et al., 2010; Basta et al., 2005). Sorption of contaminants to soil organic matter both reduces contaminant availability to plants and their leaching into groundwater. Lime-treated biosolids reduce the availability of many contaminants by increasing soil pH (Basta et al., 2005).

Application rates and techniques

Biosolids are typically applied at agronomic N rates to agricultural and forested lands to supply crop nitrogen (N) requirements; however, considerable higher application rates have been used successfully and approved by regulatory agencies for reclamation of mine lands (Sopper, 1992; Brown and Chaney, 2000; Daniels and Haering, 1994). High biosolids additions can increase the risk of short-term nitrate loss through leaching; however, such loss is permitted by regulation during initial mine land reclamation efforts in order to accelerate the rehabilitation of disturbed lands via soil restoration and increase plant productivity that will benefit long-term management of the site (Sopper, 1992; Brown and Chaney, 2000). Biosolids can also be mixed with high carbon materials such a woody residue and sawdust with the purpose of reducing nitrate leaching (Haering et al., 2000).

Biosolids applied for mine land reclamation may have variable moisture contents. The percent solids of biosolids used for mine land reclamation include liquid (2-3% solids), semi-solid biosolids (8-18% solids), and solid biosolids cake (20-40% solids) (USEPA, 2007). Liquid and semi-solid biosolids are generally applied by pumping into the field, while biosolids cake are applied with manure-type spreaders. Multiple applications of liquid or semi-solid biosolids facilitates their incorporation into the soil but can increase application costs because the soilmust be worked multiple times. In contrast, a single application is less expensive, but additional time (sometimes a complete summer period) might be needed to let the biosolids dry before incorporation (USEPA, 2007).

Permitting and regulation

Biosolids use as soil amendments for soil mine land reclamation is regulated cooperatively by the USEPA under the 40 CFR Part 503 rule, the Clean Water Act (CWA), the Resources Conservation and Recovery Act (RCRA), and the Clean Air Act (CAA). The federal Part 503 rule oversees use and disposal of biosolids, and requires that biosolids meet strict regulations (pollutant concentration limits) and quality standards (pathogen reduction) (Fact Sheet "How and who regulates the use of biosolids"). At the state level, governments implement biosolids management programs through their water and solid/waste authorities (Fact Sheet "How and who regulates the use of biosolids").

References

- Basta, N.T. 2000. Examples and case studies of beneficial reuse of municipal byproducts.In: J.F. Power, editor, Land application of agricultural, industrial,and municipal by-products. SSSA Book Ser. 6. SSSA, Madison, WI. p. 481–504.
- Basta, N.T., J.A. Ryan, and R.L. Chaney. 2005. Trace Element Chemistry in Residual-Treated Soil: Key Concepts and Metal Bioavailability. Journal of Environmental Quality. 34: 49-63.
- Brown, S., and R.L. Chaney. 2000. Combining by-products to achieve specific soil amendment objectives. p. 343-360. In J.F. Power and W.A. Dick, editors, Land Application of Agricultural Industrial, and Municipal By-Products. Soil Science Society of America, Inc., Madison, WI.
- Brown, S., M. Mahoney, and M. Sprenger. 2014. A comparison of the efficacy and ecosystem impact of residual-based and topsoil-based amendments for restoring historic mine tailings in the Tri-State mining district. Sci. Total Environ. 485-486:624–632.
- Brown, S.L., C.L. Henry, R. Chaney, H. Compton, and P.S. DeVolder. 2003. Using municipal biosolids in combination with other residuals to restore metal-contaminated mining areas. Plant and Soil. 249:203-215.
- Chen, W., A.C. Chang, L. Wu, A.L. Page, and B. Koo. 2010. Trace elements in biosolids-amended soils. In P.S. Hooda (eds), Trace elements in soil. Blackwell Publishing Ltd. UK.
- Daniels, W.L. and K.C. Haering. 1994. Use of sewage sludge for land reclamation in the central Appalachians. p. 105-121. In Clapp, C.E., W.E. Larson, and R.H. Dowdy (eds.) Sewage sludge: land utilization and the environment. SSSA. Misc. Publ. ASA, CSSA, and SSSA, Madison, WI.
- Haering, K.C., W.L. Daniels, and S.E. Feagly. 2000. Reclaiming mined lands with biosolids, manures and papermill sludges. In R. Barnhisel (eds) Reclamation of Drastically Disturbed Lands. Soil Science Society of America, Inc., Madison, WI. pp. 615–644.
- Joost, R.E., F.1. Olsen, and J.H. Jones. 1987. Revegetation and minesoil development of coal refuse amended with sewage sludge and limestone. Journal of Environmental Quality.16:65-68.
- Lu, Q., Z. L. He, and P. J. Stoffella. 2012. Land Application of Biosolids in the USA: A Review. Applied and Environmental Soil Science. Article ID 201462, p. 11.
- Nicholson, F., A. Bhogal, M. Taylor, S. McGrath, and P. Withers. 2018. Long-term Effects of Biosolids on Soil Quality and Fertility. Soil Science. 183(3):89-98.
- Sopper, W.E. 1992. Reclamation of Mine Land Using Municipal Sludge. Springer-Verlag New York Inc. Advances in Soil Science 7:351-431.
- Sopper, W.E. and S.N. Kerr. 1982. Mine land reclamation with municipal sludge Pennsylvania's demonstration program. In: W.E. Sopper, E.M. Seaker, and R.K. Bastian (ed.) Land Reclamation and Biomass Production with Municipal Wastewater and Sludge, pp. 55-74. Pennsylvania State University Press, University Park, P A.
- USEPA. 2005. Mine Site Cleanup for Brownfields Redevelopment: A Three-Part Primer. Office of Solid Waste and Emergency Response (5102G). EPA 542-R-05-030. Washington, DC.
- USEPA. 2007. The Use of Soil Amendments for Remediation, Revitalization and Reuse. Office of Solid Waste and Emergency Response (5203P). EPA 542-R-07-013. Washington, DC.