Benefits of Organic Matter in Biosolids

SCHOOL OF PLANT AND ENVIRONMENTAL SCIENCES, VIRGINIA TECH

By: Michael Badzmierowski and Dr. Gregory Evanylo

The semi-solid byproducts of wastewater treatment facilities, biosolids, are nutrient-rich, organic materials of which four million dry U.S. tons are recycled to U.S. lands annually (NEBRA, 2007). Biosolids are composed of 50-70% organic matter (often measured as volatile solids) (Li, 2013), whose functional properties can improve soil physical, chemical and biological attributes.

Physical Properties

The addition of biosolids to soils, especially those degraded or disturbed, can impart the following soil physical property benefits:

- Decrease bulk density (García-Orenes et al., 2005; Ouimet et al., 2015; Sloan et al., 2016)
- Increase porosity and aggregation (García-Orenes et al., 2005; Kirchmann and Gerzabek, 2002; Krull et al., 2004; Rawls et al., 2003)
- Increase hydraulic conductivity, infiltration and water holding capacity (Aggelides and Londra, 2000; Krull et al., 2004; Price and Voroney, 2007; Rawls et al., 2003)

Chemical Properties

The application of biosolids can reduce costs to farmers and other land managers via reduced need for inorganic fertilizer and increased crop productivity by such soil chemical property benefits as:

- Increase cation exchange capacity (i.e., holds nutrient cations and buffers against soil acidification) (Cele and Maboeta, 2016; Nielsen et al., 2003)
- Increase soil fertility from the supply of organically-bound, plant-available macronutrients (N, P, S) (Bendfeldt et al., 2001; Brofas et al., 2000; Castillejo and Castello, 2010; Cogger et al., 2006; Larney and Angers, 2012; Ouimet et al., 2015; Sloan et al., 2016). (See nutrient fact sheet for more in-depth information)
- Correct micronutrient deficiencies (Moral et al., 2002; Ozores-Hampton et al., 2011; Schroder et al., 2008, Warman and Termeer, 2005) (See nutrient fact sheet for more in-depth information)
- Correct pH of acidic and alkaline mine spoils (Basta et al., 2001; Bendfeldt et al., 2001; Brofas et al., 2000; Jones et al., 2011)
- Remediate sites previously contaminated with trace metals by binding and converting the metals to less soluble fractions (Basta et al., 2001; Brown et al., 2003)

VIRGINIA BIOSOLIDS COUNCIL

VIRGINIA TECH

Biological Properties

The organic matter from biosolids applications directly impact soil microbial communities and serves as a biostimulant to plants. The carbon-rich biosolids serves as an energy source for microbes while enhancing microbial enzymatic activity (Gardner et al., 2010; Li et al., 2013; Sullivan et al., 2006). Increased abundance of soil invertebrates and mesofauna has been attributed to biosolids applications (Cortet et al., 2013). Banks et al. (2006) found that current land application of biosolids regulations provide adequate ecosystem protection upon ecotoxicological evaluation employing earthworm mortality, growth, and reproduction; seedling germination and root elongation; microbial respiration; and nematode mortality and reproduction testing. Likewise, Shah et al. (2014) tested five different metal nanoparticles to land-applied biosolids and found that it was not toxic to the soil bacterial community.

Several organic matter constituents in biosolids (e.g., humic substances) function as biostimulants (plant growth promoter). Zhang et al. (2007, 2009, 2012), Chang et al. (2014), and Pascual et al. (2011) have shown that the humic substances and hormones within these complexes improve plant growth and resistance to abiotic stresses. (See biostimulants and biosolids fact sheet for more detailed information.)

Ecosystem Benefits

The physical, chemical, and biological benefits derived from biosolids organic matter are numerous and can have lasting beneficial impacts. The benefits from the addition of biosolids-borne organic matter improve degraded soils, such as mine tailings, disturbed urban soils, and eroded land to reestablish vegetation. The addition of organic matter stimulates microbial and plant growth via nutrient cycling, improves water infiltration and hydraulic conductivity, mitigating the impacts of large rain events, and represents a major opportunity for carbon sequestration through adding stable organic matter and the promotion of both above- and below-ground plant growth.

References

Aggelides, S.M. and P.A. Londra. 2000. Effects of compost produced from town wastes and sewage sludge on the physical properties of a loamy and a clay soil. Bioresource Technology. 71:253-259.

Banks, M.K., A.P. Schwab, N. Cofield, J.E. Alleman, M. Switzenbaum, J. Shalabi, et al. 2006. Biosolids-amended soils: Part I. Effect of biosolids application on soil quality and ecotoxicity. Water Environment Research: A research publication of the Water Environment Federation 78:2217-2230.

Basta, N.T., R. Gradwohl, K. L. Snethen, and J.L. Schroder. 2001. Chemical immobilization of lead, zinc, and cadmium in smelter-contaminated soils using biosolids and rock phosphate. Journal of Environmental Quality 30:1222–1230.

Bendfeldt, E.S., J.A. Burger, and W.L. Daniels. 2001. Quality of amended mine soils after sixteen years. Soil Science Society of America Journal 65:1736-1744.

Brofas, G., P. Michopoulos, and D. Alifragis. 2000. Sewage sludge as an amendment for calcareous bauxite mine spoils reclamation. Journal of environmental quality 29:811-816.

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.

Castillejo, J.M. and R. Castello. 2010. Influence of the application rate of an organic amendment (municipal solid waste [MSW] compost) on gypsum quarry rehabilitation in semiarid environments. Arid Land Research and Management 24:344-364.

Cele, E.N. and M. Maboeta. 2016. A greenhouse trial to investigate the ameliorative properties of biosolids and plants on physicochemical conditions of iron ore tailings: Implications for an iron ore mine site remediation. Journal of Environmental Management 165:167-174.

Chang, Z., L. Zhuo, F. Yu, and X. Zhang. 2014. Effects of biosolids on root growth and nitrogen metabolism in Kentucky bluegrass under drought stress. HortScience 49:1205-1211.

Cogger, C.G., T.A. Forge, and G.H. Neilsen. 2006. Biosolids recycling: Nitrogen management and soil ecology. Canadian Journal of Soil Science 86:613–620.

Cortet, J., F. Abonnel, J.C. Bégin, J. Béguet, A. Bouchard, D. Bru, A.M. Charissou, E.D. Chenot, D. Cluzeau, S. Colin, and F. Hafeez. 2013. Long term effects of biosolid applications on soil biological parameters. RAMIRAN 2013. 15th International Conference, Versailles, France, 3-5 June. 2013. Proceedings, Institut National de la Recherche Agronomique (INRA).

García-Orenes, F., C. Guerrero, J. Mataix-Solera, J. Navarro-Pedreño, I. Gómez, and J. Mataix-Beneyto. 2005. Factors controlling the aggregate stability and bulk density in two different degraded soils amended with biosolids. Soil and Tillage Research 82:65-76.

Gardner, W.C., K. Broersma, A. Naeth, D. Chanasyk, and A. Jobson. 2010. Influence of biosolids and fertilizer amendments on physical, chemical and microbiological properties of copper mine tailings. Canadian Journal of Soil Science 90:571-583.

Jones, B.E., R.J. Haynes, and I.R. Phillips. 2011. Influence of organic waste and residue mud additions on chemical, physical and microbial properties of bauxite residue sand. Environmental Science and Pollution Research 18:199-211.

Kirchmann, H. and M. Gerzabek. 2002. Pore size changes in a long-term field experiment with organic amendments. Developments in Soil Science. Elsevier. p. 419-423.

Krull, E.S., J.O. Skjemstad, and J.A. Baldock. 2004. Functions of soil organic matter and the effect on soil properties. GRDC Project No CSO 00029. Grains Research and Development Corporation, Kingston, ACT, Australia.

Larney, F.J. and D.A. Angers. 2012. The role of organic amendments in soil reclamation: A review. Canadian Journal of Soil Science 92:19-38.

Li, J. 2013. Effects of biosolids on carbon sequestration and nitrogen cycling. Doctoral dissertation, Virginia Tech. 225 p.

Li, S., X. Di, D. Wu, and J. Zhang. 2013. Effects of sewage sludge and nitrogen fertilizer on herbage growth and soil fertility improvement in restoration of the abandoned opencast mining areas in Shanxi, China. Environmental earth sciences 70:3323-3333.

Moral, R., J.Moreno-Caselles, M. Perez-Murcia, and A. Perez-Espinosa. 2002. Improving the micronutrient availability in calcareous soils by sewage sludge amendment. Communications in Soil Science and Plant Analysis 33:3015–3022.

NEBRA (North East Biosolids and Residuals Association), "A National Biosolids Regulation, Quality, End use and Disposal Survey—Preliminary Report, April 14, 2007. North East Biosolids and Residuals Association Web." http://www.nebiosolids.org/uploads/pdf/NtlBiosolidsReport-20July07.pdf.

Neilsen, G.H., E.J. Hogue, T. Forge, and D. Neilsen. 2003. Surface application of mulches and biosolids affect orchard soil properties after 7 years. Canadian Journal of Soil Science 83:131-137.

Ouimet, R., A.P. Pion, and M. Hébert. 2015. Long-term response of forest plantation productivity and soils to a single application of municipal biosolids. Canadian Journal of Soil Science 95:187-199.

Ozores-Hampton, M., P.A. Stansly, and T.P. Salame. 2011. Soil chemical, physical, and biological properties of a sandy soil subjected to long-term organic amendments. Journal of Sustainable Agriculture 35:243–259.

Pascual, I., J. Aguirreolea, M. Sanchez-Diaz, J.M. Garcia-Mina, M. Fuentes, and I. Azcona. 2011. Growth and development of pepper are affected by humic substances derived from composted sludge. Journal of Plant Nutrition and Soil Science 174:916-924.

Price, G.W. and R.P. Voroney. 2007. Papermill biosolids effect on soil physical and chemical properties. Journal of Environmental Quality 36:1704-1714.

Rawls, W.J., Y.A. Pachepsky, J.C. Ritchie, T. M Sobecki, and H. Bloodworth. 2003. Effect of soil organic carbon on soil water retention. Geoderma 116:61-76.

Schroder, J.L., H. Zhang, D. Zhou, N. Basta, W.R. Raun, M.E. Payton, and A. Zazulak. 2008. The effect of long-term annual application of biosolids on soil properties, phosphorus, and metals. Soil Science Society of America Journal 72:73-82.

Shah, V., J. Jones, J. Dickman, and S. Greenman. 2014. Response of soil bacterial community to metal nanoparticles in biosolids. Journal of hazardous materials 274:399-403.

Sloan, J.J., P.A.Y. Ampim, T. Boerth, J.J. Heitholt, and Y. Wu. 2016. Improving the physical and chemical properties of a disturbed soil using drying-bed biosolids. Communications in Soil Science and Plant Analysis 47:1451-1464.

Sullivan, T.S., M.E. Stromberger, M.W. Paschke, and J.A. Ippolito. 2006. Long-term impacts of infrequent biosolids applications on chemical and microbial properties of a semi-arid rangeland soil. Biology and Fertility of Soils 42:258-266.

Tian, G., C-Y Chiu, A.J. Franzluebbers, O.O. Oladeji, T.C. Granato, and A.E. Cox. 2015. Biosolids amendment dramatically increases sequestration of crop residue-carbon in agricultural soils in western Illinois. Applied Soil Ecology 85:86-93.

Warman, P. R. and W. C. Termeer. 2005. Evaluation of sewage sludge, septic waste and sludge compost applications to corn and forage: Ca, Mg, S, Fe, Mn, Cu, Zn and B content of crops and soils. Bioresource Technology 96:1029–1038.

Zhang, X., E.H. Ervin, G.K. Evanylo, and K. Haering. 2007. Drought assessment of auxin-boosted Biosolids., pp. 150–165. In Proceedings WEF/AWWA Joint Residuals and Biosolids Management Conf., Denver, CO, 15–18 Apr.

Zhang, X., E.H. Ervin, G.K. Evanylo, and K. Haering. 2009. Impact of biosolids on hormone metabolism in drought-stressed tall fescue. Crop Science 49:1893–1901.

Zhang, X., D. Zhou, E.H. Ervin, G.K. Evanylo, D. Cataldi, and J. Li. 2012. Biosolids impact antioxidant metabolism associated with drought tolerance in tall fescue. HortScience 47:1550–1555.