Benefits of Organic Matter in Biosolids

VIRGINIA TECH
SCHOOL OF PLANT & ENVIRONMENTAL SCIENCES

BY: DR. VIJAY CHAGANTI, DR. MICHAEL BADZMIEROWSKI, & DR. GREGORY EVANYLO

JULY 2025

Background

When domestic sewage is transported and conveyed to a wastewater treatment plant, it is treated to separate liquids from the solids, which produces a semi-solid, nutrient-rich product known as “sewage sludge”. The terms “biosolids” and “sewage sludge” are often used interchangeably by the public; however, the U.S. Environmental Protection Agency (EPA) and wastewater treatment facilities typically use the term “biosolids” to mean sewage sludge that has been treated to meet the requirements in the EPA’s regulation entitled, “Standards for the Use or Disposal of Sewage Sludge,” promulgated at 40 CFR Part 503, and intended to be applied to land as a soil conditioner or fertilizer.

Biosolids are primarily composed of water and organic (carbon-rich) materials. Biosolids contain macronutrients like nitrogen, phosphorus and potassium as well as micronutrients like copper, zinc and iron. Additionally, biosolids contain inert (no carbon) solids like sand, trace elements and, depending on the level of treatment, low concentrations of microorganisms. Biosolids that comply with state and federal regulations are considered safe for the environment and protective of human health and may be beneficially used for land application as a fertilizer and soil amendment, as well as for use in composted products.

Biosolids are recycled on farms and forests throughout the United States and in most developed countries worldwide. As of 2023, the EPA estimates about 60% of the total biosolids produced annually in the United States are applied for beneficial uses, while the remainder is either incinerated or disposed of in landfills.

In Virginia, the Department of Environmental Quality (DEQ), reports 37,786 acres received biosolids applications in 2024, an increase from 36,145 acres in 2023. Despite this, the acreage where biosolids are recycled represents less than 1% of all agricultural land in Virginia.

What is Organic Matter in Biosolids

Organic matter is biological material derived from living organisms, both plant and animal, or their byproducts. In essence, organic matter is anything that was once alive or is a product of something that was alive.

The typical organic matter content (often measured as volatile solids) of biosolids ranges between 50–70% (Cardenas-Talero et al., 2022). The addition of this organic matter is widely recognized for improving soil physical, chemical, and biological properties.

Soil Physical Property Benefits

Applying biosolids to soils, particularly degraded or disturbed soils, can improve physical properties in the following ways:

- Decrease bulk density, making soils less compact (Buchanan and Ippolito, 2021; Chigbo et al., 2022; Ippolito et al., 2024)
- Increase porosity and aggregation, improving soil structure (Ippolito et al., 2024; Kraemer et al., 2025; Adeli et al., 2022)
- Enhance hydraulic conductivity, infiltration, and water holding capacity, supporting better moisture management (Nicholson et al., 2018; Cooper and DeMarco, 2023; Adeli et al., 2022; Badaou and Sahin, 2022)

Soil Chemical Property Benefits

Biosolids supply both macro and micronutrients essential for plant growth and can partially substitute for inorganic fertilizers, helping farmers and land managers reduce input costs. Chemical benefits of biosolids application include:

- Increase cation exchange capacity, promoting nutrient retention and buffering soil against acidification (Cele and Maboeta, 2016; Nielsen et al., 2003)
- Enhance soil fertility through organically bound, plant-available macronutrients (nitrogen, phosphorus, sulfur) (Ippolito et al., 2021; Boudjabi & Chenchouni, 2021; Marchuk et al., 2023; Elgarahy et al., 2024; Ouimet et al., 2015; Sloan et al., 2016) — see Nutrient Fact Sheet for more details
- Correct micronutrient deficiencies, supplying essential trace elements (Moral et al., 2002; Ozores-Hampton et al., 2011; Schroder et al., 2008; Warman and Termeer, 2005) — see Nutrient Fact Sheet for more details
- Adjust soil pH in acidic or alkaline mine spoils, aiding in soil reclamation (Skowronska et al., 2020; Amorim Junior et al., 2021; Marchuk et al., 2023; Basta et al., 2001; Bendfeldt et al., 2001; Brofas et al., 2000; Jones et al., 2011)
- Remediate contaminated sites by binding trace metals and converting them into less soluble, less bioavailable forms (Ippolito et al., 2024; Ploughe et al., 2021; Li et al., 2021; Basta et al., 2001; Brown et al., 2003)

Biological Properties

The organic matter in biosolids directly supports soil biological health by stimulating microbial communities and acting as a biostimulant for plants. The carbon-rich organic material serves as an energy source for soil microbes, enhancing microbial biomass, enzyme activity, and overall microbial diversity (Schlatter et al., 2019; Morgan et al., 2024; Gardner et al., 2010; Li et al., 2013; Sullivan et al., 2006).

Biosolids applications have also been linked to increased abundance of soil invertebrates and mesofauna, contributing to a more robust soil ecosystem (Cortet et al., 2013). Studies have shown that current regulations for land-applied biosolids provide adequate protection for ecosystems, as evidenced by ecotoxicological evaluations assessing earthworm survival, growth, and reproduction; seedling germination and root elongation; microbial respiration; and nematode health (Banks et al.,

2006). Similarly, Shah et al. (2014) found that adding five different metal nanoparticles to biosolids did not harm the soil bacterial community.

Many organic matter components in biosolids, such as humic substances, also function as natural biostimulants that promote plant growth. Research has demonstrated that humic substances and naturally occurring hormones within biosolids can enhance plant growth and improve resistance to abiotic stresses (Zhang et al., 2007, 2009, 2012; Chang et al., 2014; Pascual et al., 2011). (See the Biostimulants and Biosolids Fact Sheet for more detailed information.)

Ecosystem Benefits

The combined physical, chemical, and biological benefits provided by biosolids-derived organic matter deliver multiple long-lasting advantages for ecosystems. Adding biosolids improves degraded soils, such as mine tailings, disturbed urban soils, and eroded lands, by aiding vegetation establishment and restoring soil structure.

Organic matter additions promote overall soil health by supporting plant growth, boosting microbial diversity, and enhancing nutrient cycling. Improved water infiltration and hydraulic conductivity help soils absorb and manage heavy rainfall, reducing erosion and surface runoff.

Importantly, the addition of stable organic matter through biosolids contributes to carbon sequestration, increasing soil carbon storage, boosting resilience to climate change, and supporting sustainable land management.

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