

Research Guides the Safe Reuse of Residuals for Soil Health

Over 292 million tons of municipal, agricultural, and industrial solid and liquid waste are produced each year in the U.S. Often, these wastes—also called residuals—are discarded in landfills or incinerated, which is costly to the industries and public and can pose risks to the environment and human health. Many solid and liquid wastes can be reused as soil amendments that benefit farmers and communities. However, reusing waste has been limited by lack of research, outreach, and regulation as well as concerns about potential contaminants.

Researchers at land-grant universities are working together—and with government agencies, municipalities, farmers, and others—to better understand the benefits and risks of applying solid and liquid waste to soils. With this information, they are developing technologies, strategies, and guidelines for safe, sustainable, cost-effective reuse of residuals.

The multistate framework enables researchers from different institutions and disciplines to share expertise and resources and coordinate efficient research. This ensures a comprehensive and nuanced look at the reuse of various residuals in different ways and settings. Long-term cooperation among project members and partners drives innovation and impact.

Project members evaluated how residuals can improve soil health. Researchers identified optimal application rates and quantified the economic benefits in terms of reduced fertilization costs and increased crop yield and quality. Findings guide regulations and assure farmers and communities that applying residuals is a beneficial practice. For example, project members demonstrated:

- Biosolids (treated sewage sludge from wastewater treatment plants) improve soil physical and chemical properties more than inorganic fertilizers, resulting in better vegetative productivity and less risk of nitrogen and phosphorus runoff and leaching (Colorado State University). Other studies showed that applying biosolids improves pastures (University of Florida) as well as dryland wheat yields and forest soils (University of Washington). More specifically, biosolids increase conversion of soil inorganic ammonium into the organic form plants can use (University of Kentucky). And, more crop residue carbon is transferred to soil organic carbon in fields amended with biosolids than those using conventional fertilizers, meaning less carbon is emitted to the atmosphere (Metropolitan Water Reclamation District of Greater Chicago).
- Biochar made from combusted biosolids can be a valuable soil amendment, providing nutrients and absorbing or filtering pollutants. In studies, biochar significantly increased soil carbon storage and nitrate retention in corn-soybean systems (University of Nebraska). In another study, biochar from an invasive tree species promoted higher sweet corn yields and larger corn ears than regular compost, presenting a way to control invasive trees that also benefits farmers (University of Hawaii).
- Bone meal, animal manures, composts, and sewage sludge ash (a wastewater treatment by-product) can be used as safe, renewable sources of phosphorus, an essential nutrient for crops (University of Hawaii, University of Minnesota).
- Phosphorus and nitrogen recovered from livestock and municipal wastewater can be used in agriculture (Kansas State University).



Biosolids can remediate degraded land. For example, studies showed biosolids:

- Reduce heavy metal concentrations in mine land soil (Colorado State University, University of Washington, Ohio State University).
- Lower the bioavailability of lead on shooting range soils and enable production of biofuel crops on the land (Kansas State University).
- Increase crop yields on disturbed urban soils significantly more than traditional fertilizer (University of Washington, Kansas State University).
- Are a promising option for remediating contaminated vacant lots and reducing exposure to lead, arsenic, and other legacy toxicants that pose serious health risks to communities living nearby, especially children. When added to soils, biosolids create a physical barrier and induce biogeochemical reactions that convert heavy metal contaminants to forms with low bioavailability (Ohio State University; Kansas State University).



Researchers are tracking and measuring pollutants in solid and liquid wastes and finding ways to make residuals safer for reuse. For example, project members:

- Studied the presence, movement, and effects of PFAS present in wastewater and biosolids, gaining insights into factors that reduce the potential for PFAS leaching into groundwater or accumulating in food and feed plants, livestock, and humans (University of Arizona, University of Florida, University of Georgia, University of Minnesota, New Mexico State University, Ohio State University, Pennsylvania State University, Purdue University, University of Washington).
- Tested the effectiveness of various PFAS mitigation strategies, including electrooxidation to remove and destroy PFAS from water (University of Georgia) and anaerobic digestion and thermal hydrolysis treatments to reduce PFAS in biosolids (Purdue University). Researchers also pinpointed temperatures that destroy PFAS in biochar (Colorado State University). Other efforts identified soil organisms, plants, and animal species that may be able to absorb, filter, or transform PFAS, thereby reducing soil concentrations over time (University of Georgia, University of Florida).
- Developed techniques for sampling, analyzing, and monitoring microplastics in biosolids and wastewater (University of California, Riverside; University of Florida).
- Tracked the presence of COVID-19 and flu viruses in wastewater (Pennsylvania State University).
- Showed that titanium oxide nanowire porous foams can be used with photoactivation to reduce *E. coli* in water—and the foam can be recovered and reused (Texas A&M AgriLife Research).
- Found few chemicals from pharmaceuticals and personal care products persist and move into groundwater (Purdue University).
- Identified ways to mitigate the presence, uptake, and impacts of chemicals from pharmaceuticals and personal care products. Biochars made from cotton gin waste and walnut shells effectively

remove ibuprofen, acetaminophen, and other medicines (Pennsylvania State University). Scientists also demonstrated biochar can remove some antibiotics from livestock wastewater (Kansas State University). Other studies found ways to store and apply dairy manure slurry to reduce the environmental impacts of hormones and antibiotics (Pennsylvania State University) and showed that irrigating with wastewater for only the first half of the growing season further reduces accumulation of contaminants in plants (University of California, Riverside).



Models and decision support tools and educational materials and outreach have helped farmers, utilities, community groups, government agencies, and others understand the potential benefits and risks of land application of biosolids. For example, project members:

- Provided evidence demonstrating that the U.S. Environmental Protection Agency's Part 503 Rule, which regulates metals and pathogens in biosolids, does protect crop health and the food chain.
- Developed a risk calculator for biosolids amendments to agricultural soils, which predicts the potential risk of chemicals to humans via exposure due to plant uptake, beef and milk accumulation, chicken and egg exposure, runoff to surface water, and leaching to groundwater (University of Cincinnati).
- Developed a procedure to identify the highest-priority organic chemicals in biosolids used to amend agricultural soils. Prioritization helps guide research and regulation efforts (University of Cincinnati).
- Contributed to a textbook for farmers, advisors, Extension agents, teachers, and regulatory agencies.
- Created a communications guide for speaking with and answering questions from potential biosolids users and community members.
- Wrote multiple columns and op-eds in trade journals and national magazines, explaining the science and risks of biosolids in non-scientific language.



Project Funding & Participation

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Learn more: <https://nimss.org/projects/18624>

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