Heavy Metals in Swine Manure

What Producers Need to Know to Protect Soil, Crops, and Long-Term Farm Viability

Azar Movaghatian, SDSU Graduate Research Assistant
Sushant Mehan, Assistant Professor and SDSU Extension Water Resource Engineer Specialist
John McMaine, Associate Extension Professor, Biosystems and Agricultural Engineering, University of Kentucky
Pavan Kulkarni, SDSU Field Research and Outreach Coordinator
Anthony Bly, SDSU Extension Soils Field Specialist
Robert Thaler, Farm Credit Services of America Endowed Chair in Swine Production, Distinguished Professor & SDSU Extension Swine Specialist
Sara Bauder, SDSU Extension Forage Field Specialist
John Maursetter, SDSU Environment Research Coordinator
Peter Sexton, Associate Professor, SDSU Extension Sustainable Cropping Systems Specialist and Southeast Research Farm Supervisor

March, 2026

Why This Matters for Your Farm

Swine manure is a valuable nutrient and organic matter source that supports crop production across South Dakota and the Northern Great Plains. At the same time, manure can carry small amounts of heavy metals that do not break down in soil. When manure is applied repeatedly to the same fields, these metals can slowly build up over time.

Most fields will not show immediate problems. The risk is gradual and long term. Once heavy metals accumulate, they are difficult to remove and can affect soil biology, crop growth, water quality, and future land-use options. Understanding where these metals come from and how to manage them helps protect both productivity today and flexibility for the future.

This fact sheet explains what heavy metals are, how they enter swine manure, how they behave in soil, and what practical steps producers can take to reduce long-term risks.

What Are Heavy Metals and Why Do They Matter

Heavy metals are elements that persist in the environment and do not degrade. Some metals are needed in small amounts for plant and animal health, while others have no biological benefit and are toxic even at low levels.

Heavy metals enter agricultural systems through natural processes such as soil weathering, but also through human activities including feed additives, fertilizers, industrial emissions, and manure application. Once in the soil, they tend to accumulate rather than disappear.

Key point for producers: Metals added today may still be in the soil decades from now.

Essential Versus Toxic Metals

Metals can be grouped based on their role in biological systems, as shown in Figure 1.

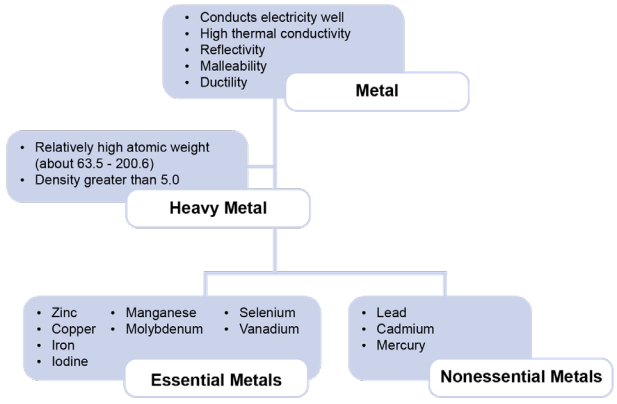

Figure 1. Classification of metals based on physical characteristics and biological function.

Essential Metals: Metals such as copper, zinc, iron, manganese, and selenium are required in small amounts for plant and animal health. Copper and zinc are commonly added to swine diets to support growth and disease resistance. At low levels, these metals are beneficial. At high levels, they become toxic. Repeated manure applications can push essential metals past the point where they help and into the range where they harm soil microbes and crops.

Nonessential Metals: Metals such as cadmium, lead, and mercury serve no biological function and are toxic even at low concentrations. These metals may enter manure through contaminated feed ingredients, mineral supplements, equipment wear, or environmental deposition.

How Heavy Metals Affect Soil and Crops

Heavy metals can interfere with normal soil and crop processes. They can:

- Disrupt soil microbial communities
- Slow nutrient cycling
- Inhibit root growth
- Reduce crop vigor and yields

Soil microorganisms are especially sensitive. When metal levels rise, microbial activity declines, organic matter decomposition slows, and nutrient availability becomes less predictable. These changes may not be visible immediately but can reduce soil resilience over time.

Why Swine Manure Is a Key Source

Livestock manure is a recognized pathway for heavy metals to enter agricultural soils. In the United States, manure application is one of the major contributors to soil inputs of copper, zinc, cadmium, lead, and several other metals.

Swine manure is unique because pigs excrete most of the metals they consume. Copper and zinc dominate the metal profile of swine manure, as shown in Figure 2. These metals are intentionally added to feed but largely pass through the animal and into manure. Repeated applications to the same fields increase the likelihood of surface soil accumulation.

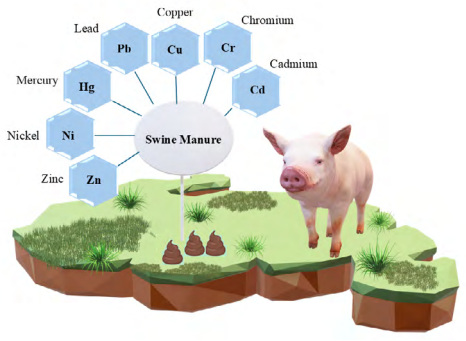

Figure 2. Heavy Metals in Swine Manure.

Where the Metals Come From

The primary source of heavy metals in swine manure is feed. Copper and zinc are commonly added to promote growth and animal health. Trace contamination can occur in mineral supplements and feed ingredients. Abrasion from equipment and environmental pollution can contribute small amounts. Studies show that up to 90 percent of dietary copper is excreted in manure. The concentration of metals in manure closely reflects feed formulation, particularly for copper and zinc. Metals are present in both solid and liquid manure fractions. Liquid manure can transport metals through runoff, leaching, or improper handling, increasing the potential for off-field movement.

What Happens to Metals After Manure Is Applied

Manure influences how metals behave in soil in both helpful and harmful ways.

Short-Term Effects: Manure adds organic matter and can raise soil pH. These changes often reduce metal mobility and plant uptake in the short term by binding metals to organic compounds or soil particles. In some systems, manure application has reduced metal uptake by crops despite increasing total metal levels in soil.

Long-Term Effects: While manure can temporarily reduce metal bioavailability, it also adds metals to the soil each time it is applied. Over years or decades, total metal concentrations increase.

Manure can hide metal problems early while building them slowly underneath.

Role of Soil Properties

Soil properties strongly influence metal behavior.

- Lower soil pH increases metal solubility and toxicity.
- Higher organic matter can bind metals but may also increase mobility through dissolved organic carbon.
- Clay and iron oxides help stabilize metals in soil.

A one-unit drop in soil pH can double the concentration of metals such as zinc, nickel, and cadmium in soil solution. Managing soil pH is one of the most effective tools for limiting metal risk.

Composting and Manure Treatment

Heavy metals do not break down during composting or anaerobic digestion. As organic material decomposes, metal concentrations often increase. Table 1 shows that composting swine manure concentrates metals such as copper, zinc, cadmium, and chromium over time. While composted manure may still be suitable for conventional farming, it can exceed regulatory limits for organic production systems. Composting changes metal concentration, not total metal load.

Metal	Day 1	Day 90	Day 270	Trend During Composting
Fe (mg/kg)	13,740	16,730	18,620	Increases steadily
Mn (mg/kg)	724	1,273	686	Peaks at 90 days
Zn (mg/kg)	677.8	859.9	555.1	Rises then drops
Cu (mg/kg)	81	134	119	Sharp rise then slight drop
Mo (mg/kg)	2.621	5.064	4.707	Increases then stabilizes
Ni (mg/kg)	20.086	29.227	30.433	Continuous increase
Co (mg/kg)	1.999	3.596	2.826	Rises then stabilizes
Cd (mg/kg)	0.895	1.449	1.185	Increases then slight drop
Cr (mg/kg)	37.794	55.845	70.854	Strong continuous increase
Pb (mg/kg)	5.719	7.916	7.000	Small rise then stable

Table 1. Changes in heavy metal concentrations during a 270-day composting process of swine manure. (Vukobratović et al., 2014).

Practical Strategies to Reduce Long-Term Risk

- Application rate is the strongest driver of heavy metal accumulation. Reducing manure rates slows the buildup of metals such as copper, zinc, and cadmium.
- Lowering copper and zinc levels in feed reduces the amount entering manure. This is one of the most effective long-term solutions but requires coordination with nutritionists.
- Regular soil testing helps track metal accumulation before it becomes a problem. Monitoring trends is more important than single-year values.
- Maintaining near-neutral pH reduces metal solubility and toxicity.
- Deep tillage can dilute surface metal concentrations but does not remove metals from the system. It should be viewed as a temporary management tool, not a solution.

What This Means for Producers

- Heavy metals accumulate slowly and persist for decades.
- Copper and zinc are the primary concern in swine manure systems.
- Short-term benefits of manure can mask long-term risks.
- Feed decisions influence soil health just as much as field decisions.
- Early monitoring protects future management flexibility.

Swine manure remains a valuable resource for crop production, but it must be managed with a long-term perspective. Heavy metals are part of the manure package. They do not disappear, and their effects build slowly.

The goal is not to avoid manure, but to apply it wisely. Balanced feed formulations, appropriate application rates, regular soil testing, and attention to soil pH allow producers to capture manure benefits while protecting soil health for future generations.

Certified Laboratories for Feed, Manure, and Soil (Including Heavy Metals) Testing

Producers are encouraged to use accredited or proficiency-tested laboratories (e.g., ISO/IEC 17025 or National Forage Testing Association participants) to ensure reliable analytical results for nutrient management, environmental compliance, and livestock health decisions.

South Dakota-Based Laboratories

South Dakota Agricultural Laboratories

Address: 1335 Western Ave, Brookings, SD 57006

Phone: (605) 692-7325

Website: https://sdaglabs.com

Services: Feed testing, fertilizer/soil analysis, and heavy metals in water and agricultural materials; ISO/IEC 17025 accredited laboratory.

Next Level Ag, LLC
Address: 617 Pine Ave N, Alpena, SD 57312
Phone: (605) 849-5227
Website: https://www.nextlevelag.com
Services: Soil and plant tissue testing with agronomic interpretation for producers.

Mid Continent Testing Laboratories, Inc.
Address: 2381 S Plaza Dr, Rapid City, SD 57709
Phone: (605) 348-0111
Website: https://www.thechemistrylab.com
Services: Environmental and water quality testing, including regulated contaminants (useful for heavy metals and compliance testing).

Regional Laboratories Commonly Used by South Dakota Producers

(Many South Dakota Extension recommendations include nearby certified labs for broader analytical capabilities.)

Ward Laboratories, Inc.
Address: 4007 Cherry Ave, Kearney, NE 68848
Website: https://www.wardlab.com
Services: Feed, manure, soil, water, and nutrient analyses; widely used in the region.

Midwest Laboratories
Address: 13611 B St, Omaha, NE 68144
Website: https://www.midwestlabs.com
Services: Feed, soil, manure, water, and comprehensive nutrient and contaminant testing.

Dairyland Laboratories, Inc.
Address: St. Cloud, MN 56302
Website: https://www.dairylandlabs.com
Services: Feed, soil, manure, water, and micronutrient analysis.

Agvise Laboratories
Address: 902 13th St N, Benson, MN 56215
Website: https://www.agvise.com
Services: Soil fertility, salinity, and environmental testing.

Minnesota Valley Testing Laboratories, Inc.
Address: 326 Center St, New Ulm, MN 56073
Website: https://www.mvtl.com
Services: Soil, manure, water, and environmental contaminant testing.

Key Considerations for Producers

- Use laboratories that participate in proficiency testing programs (e.g., NAPT/NFTA) for reliable results.
- Confirm testing scope (e.g., heavy metals, nutrients, pathogens) before sample submission.
- Follow lab-specific sampling protocols to ensure accurate interpretation.
- Request interpretation support aligned with regional recommendations (e.g., SDSU Extension, NRCS nutrient management plans)

Note: This is a non-exhaustive list of laboratories commonly used by South Dakota producers; inclusion does not imply endorsement.

References

1-Vukobratović, M., Vukobratović, Ž., Lončarić, Z., & Kerovac, D. (2014). Heavy metals in animal manure and effects of composting on it. Acta -Horticulturae, 1034, 591–598.

P-00385