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Series Guide for Tennessee Agricultural Producers Applying Biosolids: Concentration Limits for “Heavy Metals”

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Biosolids Pollutant Regulations: Human Health, Environmental Impact and Ag Productivity Considerations

A common concern agricultural producers have about land application of treated sewage sludge, herein referred to as biosolids, is the concentration of "heavy metals." In short, is it safe to land apply biosolids? The regulatory considerations for whether and how to land apply biosolids safely largely occurred in the 1980s and 1990s but are reviewed every two years by the U. S. Environmental Protection Agency (EPA) under authority of the Clean Water Act (33 USC 1345)[1]. Land application pollutant safety considerations are integrated into the Standards for the Use or Disposal of Sewage Sludge (40 CFR § 503) regulations described herein.

Broadly speaking, the Standards for the Use or Disposal of Sewage Sludge are designed to protect human health, the environment and **preserve crop and livestock productivity**. The development of these standards included a National Sewage Sludge Survey (NSSS) [3]. The NSSS tested many types of liquid, semi-solid and solid sewage sludge from 180 municipal sewage treatment plants: primary settling sludge, waste activated sludge and mixtures of primary and activated sludge treated using a wide variety of methods including thickening, dewatering, heating, liming, and aerobic and anaerobic digestion. A total of 412 pollutants were quantified in these samples across a broad range of pollutant categories [4]:

- Industrial volatile and semi-volatile organic chemicals (e.g. solvents and lubricants)
- Pesticides, herbicides and insecticides (e.g. 2,4-D and dicamba)
- Polychlorinated biphenyls (primarily used in dielectric fluids; banned in 1979)
- Dioxins (a by-product of incineration and herbicide/organic chemical manufacturing)
- Dibenzofurans (a by-product of incineration; used in insecticide and vinyl manufacturing)
- Industrial Elements: aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silicon, sodium, thallium, vanadium and zinc
- Cyanide (highly toxic; used in electroplating/metal finishing)

The NSSS was used to characterize pollutant concentrations across a size range of wastewater treatment plants [5, 6]. The outcome was that a subset of pollutants was subject to a risk assessment for biosolids land application using 14 exposure pathways (**Table 1**):

- **Elements:** arsenic, cadmium, chromium, cobalt, copper, fluoride, iron, mercury, molybdenum, nickel, selenium and zinc
- **Organics:** aldrin/dieldrin, benzo(a)anthracene, benzo(a)pyrene, bis(2-ethylhexyl) phthalate, chlordane, DDD/DDE/DDT, heptachlor, hexachlorobenzene, hexachlorobutadiene, lindane, methyl bis (2-chloro-aninline), methylene chloride, n-nitroso dimethylamine, pentachlorophenol, pcbs, toxaphene, trichloroethylene and tricresyl phosphate.

All of the organic pollutants were eliminated as sources of risk because of their very low biosolids concentrations, in-field biodegradability, and production bans. Nine elements presented risk warranting final regulation (**Table 2**). Several of these are commonly considered "heavy metal" pollutants because they are dense metallics, are commonly used in industrial processes and thus present in biosolids, and are persistent in soils and accumulate to concentrations that present human health, agricultural productivity, and environmental risks [7].

Table 1. Lifetime risk assessment process used to set protective pollutant concentration limits to safely land apply biosolids.

Category	Exposure Pathway	Pathway Description
Human Health	Biosolids→Human	Ingesting biosolids (child, aged 1-6)
	Biosolids→Soil→Plant→Human	Eating crops grown in biosolids amended soil
		Eating plants grown in biosolids amended garden soil
	Biosolids→Soil→Plant→Animal→Human	Ingesting milk & meat from animals pasturing biosolids amended soil
	Biosolids→Soil→Air→Human	Inhaling pollutants volatilized from biosolids amended soil
	Biosolids→Soil→Airborne Dust→Human	Inhaling dust from biosolids amended soils (during tillage)
	Biosolids→Soil→Ground Water→Human	Drinking water containing pollutants leached from biosolids amended soil
	Biosolids→Soil→Surface Water→Human	Eating fish & drinking water contaminated by biosolids amended soil
Ecological Health	Biosolids→Soil→Animal	Livestock ingesting pollutants from biosolids amended soil
	Biosolids→Soil→Plant	Plant toxicity caused by pollutants in biosolids amended soil
	Biosolids→Soil→Plant→Animal	Livestock ingesting plants grown in biosolids amended soil
	Biosolids→Soil→Soil Biota	Soil organism (earthworm) ingesting pollutants in biosolids amended soil
	Biosolids→Soil→Soil Biota→Predators	Soil predators (shrew/mole) ingesting biota in biosolids amended soil

Table 2. Biosolids pollutants targeted by EPA for regulatory oversight.

Pollutant	Pollutant Source for Contaminated Biosolids	Pollutant Risks & Limiting Exposure Pathway
Arsenic	Wastewater from metal plating/finishing and electronics, pigment/paint manufacturing, formerly treated wood plants; Improper disposal of herbicides and pesticides	Human carcinogen **Biosolids→Human**
Cadmium	Wastewater from metal plating/finishing and plastics, battery, pigment/paint & electronics manufacturing	Human carcinogen; Gastrointestinal disease & kidney damage **Biosolids→Soil→Plant→Animal→Human**
Copper	Corrosion of copper plumbing; Wastewater from metal plating/finishing, chemical and electronics manufacturing	Plant toxicity at high soil concentrations **Biosolids→Soil→Plan**
Lead	Corrosion of lead plumbing/solder; Wastewater from battery, electronics and ceramics manufacturing	Irreversible brain damage in children; Joint disease in adults **Biosolids→Human**
Mercury	Wastewater from dental/healthcare facilities and metal plating, electronics, and pigment/ dye manufacturing; Atmospheric deposition from coal and waste combustion	Methylmercury accumulates in fish/shellfish, con-sumption causes systemic birth defects **Biosolids→Soil→Plant→Animal→Human**
Molybdenum	Wastewater from metal plating/finishing, petroleum refineries, and pigment/paint, electronics & catalyst manufacturing	Causes copper deficiency in ruminants **Biosolids→Soil→Animal**
Nickel	Wastewater from metal plating/finishing and petrochemical plants & stainless steel, battery and electronics manufacturing	Allergen; nickel compounds can be carcinogenic; Plant toxicity at high soil concentrations **Biosolids→Soil→Plant**
Selenium	Wastewater from electronics, glass, pigment/dye/toner and chemical manufacturing; Personal care products and pharmaceuticals	Gastrointestinal illness **Biosolids→Soil→Animal**
Zinc	Corrosion of galvanized plumbing; Wastewater from metal plating/finishing and pigment/ paint, lubricant manufacturing	Plant toxicity at high soil concentrations **Biosolids→Soil→Plant**

Maximum Pollutant Concentrations

The Standards for the Use or Disposal of Sewage Sludge require testing for the regulated "heavy metals" in **Table 2**. The sampling frequency depends on how much biosolids the wastewater treatment plant generates that are intended for land application (it is possible to reduce the sampling frequency if concentrations are consistently below regulatory limits):

- Up to 290 tons → one per year
- 290 – 1,500 tons → four times per year (every three months)
- 1,500 – 15,000 tons → six times per year (every other month)
- > 15,000 tons → twelve times per year (monthly)

Each test result is compared with maximum allowable or "ceiling" pollutant concentrations published in the Standards for the Use or Disposal of Sewage Sludge regulations (**Table 3**). These ceiling limits reflect a threshold for maintaining acceptable risk-based exposure through the pathways described in **Table 1** (e.g. a maximum increased lifetime cancer risk exceeding 1:100,000 exposed individuals). **Biosolids that exceed the ceiling limit for any single pollutant in Table 1 cannot be land applied.**

Prior to the 1990s, exceedances for the standards published in **Table 3** were not uncommon for copper, cadmium, nickel and zinc [8]. However, Section 307 of the Clean Water Act (33 USC § 1317) requires pre-treatment standards for industrial and commercial wastewater discharges to municipal wastewater collection system. These standards are designed, in part, to prevent contamination of biosolids and have dramatically reduced the concentration of "heavy metals" in biosolids [2]. A review of the average 2024 biosolids pollutant concentration monitoring results for the Kuwahee WWTP in Knoxville, TN, is illustrative: the concentrations of regulated pollutants are far below the ceiling concentration limits (**Table 3**).

Table 3. Biosolids ceiling concentration limits for "heavy metal" pollutants (dry basis); 2024 pollutant concentration monitoring results for the Kuwahee Wastewater Treatment Plant (WWTP) in Knoxville, TN, are included for reference.

Ceiling limits			Kuwahee WWTP Results
Pollutant	**mg/kg**	**lb/ton**	**mg/kg**
Arsenic	75	0.15	5
Cadmium	85	0.17	1
Copper	4,300	8.6	234
Lead	840	1.7	18
Mercury	57	0.11	0.3
Molybdenum	75	0.15	5
Nickel	420	0.84	19
Selenium	100	0.2	3
Zinc	7500	15	709

Monitoring Threshold for the Cumulative Land Loading of Regulated Pollutants

If the ceiling concentration thresholds in **Table 3** are met, the Standards for the Use or Disposal of Sewage Sludge employ a secondary set of lower pollutant concentrations that affect the recordkeeping required to land apply biosolids in bulk. If the concentration for any one of the regulated pollutants exceeds the values in **Table 4**, the cumulative pollutant loading must be continuously tracked for each field that receives biosolids. Tracking applies to any source of biosolids applied to a field that has received biosolids containing any single pollutant concentration exceeding the pollutant concentrations in **Table 4**. A field specific lifetime loading limit (**Table 4**) is then used to assure that an acceptable threshold for the risk-based exposure pathways in **Table 1** are maintained continuously across what can be many years of repeated biosolids applications to the same field.

As noted previously, Section 307 of the Clean Water Act (33 USC § 1317) requires pretreatment of industrial and commercial wastewater discharges to municipal wastewater collection systems. These pretreatment requirements have dramatically reduced pollutant concentrations in municipal wastewater so that the average pollutant concentrations in the United States have for some time been below the pollutant concentrations limits in **Table 4** [2].

If a wastewater treatment plant (generator) wants to land apply biosolids in Tennessee, and the pollutant concentrations in **Table 4** are exceeded, or if the biosolids do not meet certain pathogen and vector attraction reduction treatment standards, the generator must first apply for a Tennessee Biosolids State Operating Permit. These permits require biosolids analytical (**Table 4**) and cumulative loading reporting (**Table 4**).

Table 4. Biosolids pollutant concentration and field specific cumulative loading limits (dry basis). The 2024 pollutant concentration monitoring results for the Cleveland Utilities Wastewater Treatment Plant in Cleveland, TN, are provided for reference; the average US biosolids concentration for Cd, Cu, Pb, Ni and Zn, as of 2014, are shown in parentheses [2].

Pollutant	Pollutant Concentration (for load limit monitoring)		Cleveland WWTP	Cumulative Loading Limit	
	mg/kg	lb/ton	mg/kg	kg/ha	lb/ac
Arsenic	41	4	0.15	41	37
Cadmium	39	2	0.17 (2.7)	39	35
Copper	1,500	340	8.6 (569)	3,000	1,338
Lead	300	19	1.7 (80)	1,500	268
Mercury	17	1	0.11	17	15.2
Nickel	420	24	0.84 (53)	420	375
Selenium	100	9	0.2	100	89.2
Zinc	2,800	1,009	15 (1,014)	2,800	2,498

TDEC Biosolids State Operating Permit Database

The Tennessee Department of Environment and Conservation Division of Water Resources (TDEC-DWR) issues the Tennessee Biosolids State Operating Permit to any utility that land applies regulated biosolids. The state permit regulations were recently finalized after a lengthy public comment period in TDEC-DWR publication CN-1393.

These permits are maintained in an online database with public access within the TDEC-DWR Data Viewer (**Figure 1**). Agricultural producers can follow this Data Viewer link to review documents associated with maintenance of a particular Tennessee Biosolids State Operating Permit, including the monitoring results for the regulated pollutants in **Table 2**.

Figure 1. *Facilities covered or seeking coverage under the Tennessee Biosolids State Operating Permit: active (red diamonds), exceptional quality biosolids (green stars–land application is not regulated), pending (open circles), and renewed (open triangles).*

Conclusions

Perhaps the most common question the University of Tennessee Extension receives from agricultural producers considering the land application of biosolids is a fear that "heavy metals" will negatively affect human/animal health and/or permanently lower agricultural productivity. After all, there is no way to undo biosolids applications. **This concern with heavy metals contamination is now unfounded.** Many pollutant exposure pathways were considered in the process used to develop the Standards for the Use or Disposal of Sewage Sludge (**Table 1**). Four decades ago, before industrial and commercial wastewater pretreatment standards were in effect, nine pollutants including several "heavy metals" were regulated based on a risk assessment (**Table 2**). The Standards for the Use or Disposal of Sewage Sludge set protective maximum concentrations for these elements (**Table 3**). Further, if concentrations exceed pollutant concentration limits (**Table 4**), field specific cumulative load monitoring is required to assure that acceptable risk levels are maintained across multi-year biosolids applications. Even so, industrial wastewater pretreatment has dramatically reduced their concentrations in biosolids (**Table 4**) [2]. If you are an agricultural producer considering land applying biosolids, you can consult a database for the Tennessee Biosolids State Operating Permit and observe for yourself the **Table 2** monitoring results for a utility near you (**Figure 1**).

Today, more recent pollutants of concern are more relevant than "heavy metals," including per- and polyfluoroalkyl substances (PFAS) and pharmaceuticals and personal care products. These pollutants will be reviewed in further series publications to help agricultural producers determine whether pollutant risks outweigh the benefits biosolids offer in the form of plant nutrients and organic matter.

References

1. *United States Code*. 1972.
2. Hundal, L.S., et al., *Improvements in Biosolids Quality Resulting from the Clean Water Act.* Water Environment Research, 2014. 86(2): p. 134-140.
3. U. S. Environmental Protection Agency, *Sampling procedures and protocols for the national sewage sludge survey.* 1988.
4. U. S. Environmental Protection Agency, *Analytical methods for the national sewage sludge survey*. 1992.
5. U. S. Environmental Protection Agency,*Statistical support documentation for the 40 CFR, Part 503 final standards for the use and disposal of sewage sludge.* 1992.
6. U. S. Environmental Protection Agency, *Statistical support documentation for the 40 CFR, Part 503 final standards for the use and disposal of sewage sludge.* 1992.
7. Page, A., T. Logan, and J. Ryan, *Land Application of Sludge: Food Chain Implications*. 2018.
8. Mumma, R.O., et al., *National survey of elements and other constituents in municipal sewage sludges*. Archives of Environmental Contamination and Toxicology, 1984. 13(1): p. 75-83.

Online Resources

Clean Water Act of 1972 (CWA: 33 USC 1345): law.cornell.edu/uscode/text/33/1345

The Standards for the Use or Disposal of Sewage Sludge (40 CFR § 503): ecfr.gov/current/title-40/chapter-I/subchapter-O/part-503

Tennessee Biosolids State Operating Permit: tn.gov/environment/permit-permits/water-permits1/biosolids-state-operating-permit.html

Tennessee Department of Environment and Conservation – Division of Water Resources Data Viewer: dataviewers.tdec.tn.gov/dataviewers/f?p=2005:34001:13177164067383:::RR,34001:IREQ_PERMIT_TYPE:Biosolids

General State Operation Permit for the Land Application of Non-Exceptional Quality Biosolids, state of Tennessee publication CN-1393: dataviewers.tdec.tn.gov/dataviewers/apex_util.count_click?p_url=BGWPC.GET_WPC_DOCUMENTS?p_file=624926347417662638&p_cat=DOCS&p_id=624926347417662638&p_user=GUEST&p_workspace=19833722515258996

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