

## 2.13 Land Application of Sewage Sludges

Municipal sewage sludges (also known as biosolids) are organic-rich solids (usually greater than 50 percent organic matter) that contain sufficient N (2–7 percent) and P (1–5 percent, equivalent to 2–10 percent  $P_2O_5$ ) to make them potentially useful as farm fertilizers and a source of organic matter. Sludges, however, are low in K. Additions of sludge can improve the physical properties of soil such as bulk density, aggregation, porosity, and water retention. Increased crop yields with appropriate application have been documented.

Sewage sludges are a by-product of sewage treatment and contain not only nutrients and organic matter but also contaminants such as metals and synthetic organics discharged into the sewers from homes, industries, and businesses and leached from pipes. Because most heavy metals remain in the soil for a very long time, any additions should be considered permanent additions to the total quantity in the soil. Sludges also contain high levels of pathogens, which can be reduced or eliminated through sludge treatment.

Sludges can be applied to land directly or may be processed into fertilizer pellets, compost, or a liming agent (through the addition of a product such as cement kiln dust). The amount and type of industrial inputs, pretreatment of industrial discharges to reduce contaminants, and treatment of the sludge to reduce pathogens all affect the quality of sludges. Even at a specific treatment plant, sludge quality will vary over time.

Growers using sewage sludges should obtain analytical information from the supplier on the concentration of nutrients, metals, and synthetic organic chemicals in the particular sludge or sludge product they are applying to their land. Regulations require testing only for a very limited list of regulated metals and only at intervals determined by the size of the sewage plant (infrequent testing at smaller plants). Analyses for antimony, arsenic, beryllium, boron, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, silver, and zinc as well as nutrients are recommended. Tests for organic chemicals, including dioxins and PCBs, are expensive but are recommended, especially when cement kiln by-products or incinerator ash are a component of the sludge product or if sludge is used on livestock farms (though this use of sludge is not recommended). Brominated flame retardants and nonylphenols have been found at high levels in sludges.

Land application of sludges is regulated under state (Part 360 of NYS DEC regulations) and federal (Part 503) regulations. Municipalities in New York State may also adopt local rules. Where different, the most stringent of the federal, state, or local rules must be followed. NYS DEC limits for sludges generally are slightly more restrictive than EPA rules, and cumulative load limits apply to them (Table 2.13.1). Manufacturing of sludge products (such as composts and N-Viro) is regulated by NYS DEC. Under

federal rules, sludges are classified based on the extent of pathogen treatment. Class A is treated to essentially eliminate pathogens. Class B receives some pathogen treatment but still has significant levels. DEC rules require detailed site-specific analysis and controls, including record keeping and application rates limiting the cumulative addition of metals for application of class B sludges but not for application of class A sludge products.

Regulatory limits have been set by EPA for nine heavy metals based on a risk assessment analysis. Although EPA considered applying limits to 50 pollutants, the list was reduced owing to various practical considerations (insufficient data) and risk-based analysis (risks of harm to humans and the environment at levels typically found in sludges were low). The regulatory limits established by EPA include standards to be met for a sludge to qualify as “exceptional quality” (EQ) (see Table 2.13.1). Class A EQ sludges and sludge products should be applied at agronomic rates, but their use does not require site-specific permits or record keeping. “Ceiling limits,” significantly less stringent than the EQ limits, have been set by EPA for the same nine metals. Federal rules allow sludges not meeting the EQ limits but within the ceiling limits to be applied, but the cumulative load of metals applied over time must be calculated and must be less than that allowed under the regulations (see Table 2.13.1).

In New York State, sludges processed into a sludge product are regulated under section Part 360. The producer of the product must obtain a permit, but permits for sites where the product is used and record keeping are generally not required. Check with NYS DEC to determine applicable requirements before applying sludge or sludge products. Food processors and farm lenders may apply further restrictions; thus, checking on their policies is recommended before application.

Although many studies have been done on the land application of sludges, scientific uncertainties remain, particularly with respect to long-term soil productivity, health impacts to neighbors from airborne pathogens, and ecological safety. High application rates over a number of years of sludges with significant contaminant concentrations could result in soil levels of certain toxic metals, or organic chemicals, or both, which might impair soil productivity and present risks to human, agricultural, and environmental health. If sludge is used, limiting the amount of metals in the soil is advised (see Table 2.13.2). For a number of reasons, including the potential ingestion of sludged soil by children and the uptake of cadmium by plants, the use of sludges in home gardens is not recommended.

Odors and airborne toxins and pathogens can be a significant issue. Proper management can help, including prompt incorporation into the soil, avoiding stockpiling, and maintaining setbacks from neighbors. Proper management is also required to minimize the likelihood of ground and surface water pollution.

Liability is a concern to some growers. It may be useful to obtain indemnification from the municipality generating the sludge and any vendor involved in its processing or delivery. Vendors should certify that any sludge delivered will meet certain standards and agree to defend the farmer if a lawsuit is presented. The farmer may be asked to certify that he or she will apply the sludge in conformance with specified best management practices. If problems such as livestock decline do occur, establishing cause is very difficult.

### 2.13.1 Application Rates

The application rate for sludges is generally based on the nitrogen requirements of the crop to which it is applied and the nitrogen content of the sludge. A rate of 5-10 tons dry weight/acre is typical. For sludge products containing significant lime, the rate of application is usually based on the need for adjusting soil pH. A rate of 1-3 tons/acre every other year is typical, although practical limitations to accurate spreading at low rates may result in significantly more being applied.

### 2.13.2 Nutrients

As with other fertilizers, the beneficial effects of the nutrients present in sludges must be integrated into a nutrient management plan for each field on the whole farm to ensure that groundwater is not contaminated with nitrates and surface water with phosphate. This is particularly important on livestock farms where manure already provides a large source of nutrients. Generally, if sludge is used as the sole source of N for crops, over a number of years excess P will build up in the soil, a possible concern for contamination of surface waters. Because our knowledge of the mineralization rate for N in sludges is inadequate and because the nutrient content varies widely, even in sludge from a single sewage treatment plant, agronomic application rates are difficult to determine. Caution is needed to avoid the potential for nitrate contamination of groundwater while providing adequate nutrients for crops.

### 2.13.3 Metals

Although some metals in sludges are necessary micronutrients (e.g., copper and zinc), at higher levels they may be harmful to crops, particularly those grown on acidic soils. Alfalfa and clover are particularly sensitive to these metals, but corn is not. Several other metals such as lead, mercury, and cadmium as well as toxic organic chemicals (PCBs, for example) that may be present in sludges provide no benefits and could be harmful to humans.

As shown in Table 2.13.2, typical ranges of metal concentrations in New York sludges greatly exceed those in uncontaminated soils. As a consequence, land application of sludges increases the concentration of metals to an extent determined by the cumulative application of sludge. Most heavy metals remain in the soil for long periods of time, ranging from several decades (e.g., cadmium) to many

centuries (e.g., lead). Crops grown on soils treated with sludges containing elevated trace element concentrations show increased concentrations of cadmium, molybdenum, and several other elements for at least several decades following cessation of sludge application. Cadmium in adult human diets in industrialized countries is estimated to average about 25–50 percent of the acceptable daily intake limit, and young children may already exceed the acceptable limit. Therefore, further increases of cadmium in food crops should be avoided. Restrictions on cadmium content of grains in some European countries (e.g., maximum level of 0.13 ppm in Germany) may affect the potential to export when cadmium levels are increased in crops.

It is recommended that sewage sludges or sludge products with trace element concentrations exceeding the recommended maximum values in Table 2.13.2 (last column) not be applied to agricultural land at high rates or for long periods of time. Furthermore, it is recommended that the cumulative load of metals in the soil resulting from repeated applications not exceed the values in the last column of Table 2.13.2. Soil testing before sludge application is recommended to determine background metal levels. Where sludges or sludge products containing elevated metal levels are being applied, soil pH should be maintained near 6.5–7.0 because cadmium as well as some other toxic metals are more plant-available and leachable in acidic or highly basic soils.

### *General Concerns with Metals in Sludges* (2.13.3.1)

1. Certain metals may become toxic to crops after repeated applications of sludges. The metals most likely to cause growth problems in crops are copper, zinc, and nickel, partly because they can occur at high concentrations in sludges (see Table 2.13.2). Short-term damage to crops from salinity or boron sometimes occurs with heavy applications of certain sludges.

2. Certain metals are particularly toxic to animals and humans, notably lead, cadmium, and mercury. Other metals of concern for animals and humans are arsenic, selenium, and molybdenum. Copper deficiency in ruminants can result from intake of excessive sulfur and/or molybdenum, which can be present at high concentrations in sludges. Not all toxic metals are regulated or tested for.

3. Whereas many elements are not taken up substantially by crops, others such as cadmium, molybdenum, and selenium are taken up and may be a concern for animal and human health. Although lead is not generally taken up by crops through the root system, dust contamination of crops, particularly leafy vegetables, can result in elevated lead levels where soils have accumulated substantial lead.

### 2.13.4 Synthetic Organic Chemicals

Sludges may contain volatile organic compounds (VOCs) such as benzene, chlorinated benzenes, chloroform,

cyclohexane, octane, tetrachloroethylene, trichloroethylene, toluenes, and xylenes. These compounds are generally volatile, so most of them are lost to the air fairly quickly following the spreading of sludge on the soil surface. Phthalates, phenols, and polyaromatic hydrocarbons (PAHs) also occur, and surfactants from detergents as well as brominated flame retardants occur at much higher concentrations. The effects of these chemicals on soil properties and organisms are not well known.

Organochlorine pesticides as well as polychlorinated biphenyls (PCBs), dioxins, furans, and other persistent trace organic contaminants are present in some sludges, generally at low levels, though at levels much higher than those present in uncontaminated soils. Some cement kiln dust and incinerator ash, which may be mixed with sludges to produce liming materials, may contain elevated concentrations of such organics, particularly if alternative fuels such as hazardous wastes are used as fuel. Dioxins (as well as other chlorinated organics such as PCBs) are absorbed into the fat of grazing animals and transferred into the milk and meat. Until more information is available on the transfer of these very persistent organic chemicals from soil into animals through feed or by grazing and on their toxicity to humans and ecological impact, great caution in the use of sewage sludges on livestock farms is advised.

Current regulations do not set standards or require testing of sludges for organic chemicals (with the exception of a PCB standard under DEC Part 360 rules), and such testing can be expensive, depending on what contaminants are included. It is strongly advised that if growers choose to apply sludge to pasture or forage, they require suppliers to provide information on these chemicals before application.

### 2.13.5 Pathogens

Sewage sludges contain many different pathogens, or disease-causing organisms. Class B sludges have received treatment to reduce, but not eliminate, pathogens. Class A sludges have been treated (usually through high temperatures) with a goal of eliminating pathogens. Farmers and farmworkers handling Class B sludges are advised to take precautions to avoid direct contact or inhalation of dust or spray during and subsequent to application. The possibility that neighbors could be exposed to pathogens by wind transport or water runoff is a concern. Immediate incorporation into the soil can reduce those risks. Current DEC regulations restrict public access and the harvesting of food crops from lands to which sludges have been applied. Grazing animals are to be kept off sites that receive Class B sludge for 30 days.

#### *Pathogens in Class B Sewage Sludges (2.13.5.1)*

**Bacteria.** The occurrence of bacteria in sludges is highly variable depending on the disease incidence in the community. The amount of pathogenic bacteria is reduced but not eliminated by conventional sewage treatment (e.g., anaerobic digestion). Special treatment of sludge, such as

pasteurization (heating), eliminates bacteria. Regrowth can occur when processes reduce their numbers but do not eliminate them or if the pathogens are reintroduced. Once applied to soil, the numbers of pathogenic bacteria decline rapidly at the surface, but decline in the soil below the surface is much slower. High temperatures, sunlight, and soil drying assist the decline.

**Viruses.** Sludges contain highly variable densities of viruses; those of concern include polio, hepatitis A, and rotaviruses. They can survive in soil below the surface for weeks to a year, depending on environmental conditions.

**Protozoa.** The cysts of protozoa such as *Giardia* and *Cryptosporidium* that invade the human gastrointestinal system and cause disease are found in sewage sludges. Cysts have been reported in sewage sludge processed by anaerobic digestion, indicating that some fraction of the protozoa survive this process. Protozoa in soils may survive only a few days or weeks.

**Helminths.** This group of organisms includes roundworms and tapeworms, parasites that can ultimately cause severe health problems. Helminth ova are resistant to environmental exposure and treatment with lime and chlorine, but can be inactivated at temperatures above 50° C (122° F). The ova of *Ascaris* sp. can survive for years under favorable conditions and have the highest concentration of all helminths detected in sewage sludges. It should be assumed that these organisms can persist for many years after Class B sludges have been tilled into the soil.

### 2.13.6 Sludge Guidelines

#### *Sludge and Soil Quality (2.13.6.1)*

1. Limit application of sludges so that the soil concentrations in Table 2.13.2 (far right column) are not exceeded. The numbers are for recommended maximum soil concentrations and will therefore depend on initial soil concentrations, the concentration of the contaminant in the sludge, the total loading of sludge applied, and any losses (e.g., through leaching). Limiting application to these quantities will also help prevent excessive contamination with currently unregulated contaminants. Sludges with contaminant concentrations not exceeding the levels in ppm listed for maximum soil concentrations in Table 2.13.2 may be applied in unlimited cumulative quantity without exceeding the recommended soil concentrations for these contaminants. (Application at appropriate annual rates to ensure that nutrient levels are not exceeded is still required.) For sludges exceeding the maximum concentrations recommended in Table 2.13.2, calculations should be made to determine the cumulative amount of sludge that may be applied without exceeding the recommended soil concentration.

To determine the total number of tons/acre that may be applied for a sludge with measured contaminant levels, use the following equation: Total cumulative application in

tons/acre=1,000 multiplied by (max. soil concentration in ppm minus background soils concentration in ppm) divided by sludge contaminate concentration in ppm. For example, if a sludge contains Cd at 10 ppm, background soil is 0.2 ppm, and the recommended maximum soil concentration of 2 ppm is used, a total of 180 tons/acre may be applied  $[1,000 \times (2 \text{ ppm} - 0.2 \text{ ppm}) / 10 \text{ ppm}]$  without exceeding the recommended maximum soil concentration, assuming all of the cadmium applied remained in the soil.

2. As a general precaution, do not apply sludge to land at high rates or for many applications if the sludge has contaminant concentrations greater than those listed as recommended maximum soil concentrations in Table 2.13.2.

3. Applying sludge may result in excessive application of nutrients and cause leaching of nitrogen and excess enrichment of phosphorus in soils, particularly on livestock farms where excess nutrients may already be present. Therefore, apply sludge only according to a nutrient management plan.

### ***Testing (2.13.6.2)***

1. Require the supplier to provide information on the content of nutrients and contaminants. Consumers, including farmers, should compare various products to determine the one with the lowest contaminant levels and optimal nutrient content. In addition to the regulated contaminants, request information about synthetic organic chemicals (including PCBs and dioxins and furans), antimony, beryllium, boron, chromium, and silver. While not recommended, if the land will be used for grazing or growing forage, also request analyses for fluoride, iron, molybdenum, and selenium and consider dietary metal ratios.

Ideally, the evaluations will pertain to the specific load of sludge or product being used (not to products from previous loads). When this is not possible, reports from several different sampling times should be compared to ensure that levels are relatively constant. Select only products with consistently low levels of contaminants.

2. Test soils before application to determine pH, nutrient requirements, and metals concentrations. Avoid over-application of metals by testing for background levels before application and test at least every five years in a sustained application program.

3. Test for metals, nitrates, and pathogens in water wells that are near and down gradient of fields where sludges have been applied.

**Note:** Soil analyses for some constituents may be obtained through Cornell Cooperative Extension. Contact the

Department of Health or NYS DEC for information on other laboratories certified to perform analyses.

### ***Uses and Management Practices (2.13.6.3)***

1. Caution is advised regarding application of sewage on land used for forage production or grazing. Toxicities can result from imbalances in trace elements, particularly molybdenum, selenium, and copper. For Class B sludges, pathogens are a concern. If sludge or sludge products are used, do not apply to standing forage. Incorporating sludge into soils is particularly important, and analysis of the ratio of various metals in the animal diet is recommended.

2. Apply sludge as you would manure, using a calibrated spreader to ensure accurate, uniform distribution. Prevent overapplication and avoid hot spots. If someone else is applying the sludge, make sure he or she spreads properly. Visit fields where that person has previously applied sludge.

3. Maintain soil pH at 6.5–7.0 to minimize plant uptake and leaching unless contaminant levels are low, similar to background soil concentrations or recommended soil values in Table 2.13.2.

4. Incorporate sludge to prevent odor problems, dispersal of airborne pathogens, enrichment of surface water runoff, deposition of dust or spray on crops, and ingestion by livestock. Spread sludges within one or two days of delivery and incorporate within 48 hours after application. When using sludges assume odors will always be a concern for neighbors.

5. Maintain setbacks from streams, ponds, wells, and property lines.

6. Avoid application on steep slopes, on saturated soils where runoff is excessive, or on shallow or extremely well-drained (coarse) soils where percolation to groundwater may be rapid.

7. Avoid contact with and inhalation of Class B sludges to reduce pathogen hazards.

8. Take delivery of sludge only after analytical reports have been examined, application plans have been understood and agreed to, and best management practices have been established.

9. Check with NYS DEC, your farm credit organization, and the person buying your crops to determine any restrictions.

10. Avoid access to sludge products by children. (Use of sludge in home gardens presents the greatest potential for children's exposure.)

**Table 2.13.1. Current EPA and DEC standards for land application of sewage sludges**

Contaminant	NYS DEC Sludge and sludge product, monthly average <sup>1</sup> (ppm)	NYS DEC Sludge + sludge product max (ppm) <sup>2</sup>	EPA 503 EQ limit (ppm)	NYS DEC Cumulative limit <sup>3</sup> (lb/A; kg/ha)	EPA 503 Cumulative limit (kg/ha)
Arsenic	41	75	41	none	41
Cadmium	21	75	39	3/4	39
Chromium	1,000	1,000	none	300/446	none
Copper	1,500	4,300	1,500	75/112	1,500
Lead	300	840	300	267/267	300
Mercury	10	57	17	none	17
Molybdenum	40	75	none <sup>4</sup>	none	none
Nickel	200	420	420	30/45	420
Selenium	100	100	100	none	100
Zinc	2,500	7,500	2,800	150/223	2,800

<sup>1</sup>Part 360-4+5 establish maximum monthly average concentrations.

<sup>2</sup>Part 360-5 establishes maximum not-to-exceed concentrations.

<sup>3</sup>Part 360-5. Amount that may be added over time. Lower number applies to Ag Soil groups 1–3, higher number to groups 4–10. Does not apply to sludge products.

<sup>4</sup>EQ limit for molybdenum was deleted from U.S. EPA rules pending reconsideration.

**Table 2.13.2 Recommended maximum soil concentrations for sludge contaminants**

Contaminant	Typical Sludge Conc. <sup>1</sup> (ppm)	Typical NYS Ag Soil (ppm)	Recommended Soil Maximum Concentration (ppm)
Arsenic	3–10	<9	1–10 <sup>2</sup>
Cadmium	2–15	0.2	1.5 <sup>3</sup>
Chromium	50–500	52	100–600 <sup>4</sup>
Copper	300–1,500	20	50–150 <sup>5</sup>
Lead	100–300	15	<sup>6</sup>
Mercury	1–10	0.1	1 <sup>7</sup>
Molybdenum	5–50	<1	2 <sup>8</sup>
Nickel	10–150	16	30–60 <sup>9</sup>
Zinc	500–2,500	60	85–300 <sup>10</sup>
PCBs	<5		1 <sup>11</sup>

<sup>1</sup>Based on a survey of New York State sludges (NYS DEC, 1994).

<sup>2</sup>Risk assessment based on child ingestion, and 0.0003 RfD suggests 1 ppm concentration limit for sludges used at home (Texas Natural Resources Commission, 1996). Background soil often exceeds 1 ppm so a range suggested is potentially acceptable.

<sup>3</sup>Uptake of Cd into crops consumed by humans is the concern. For soils never to be used for crops for human consumption, Cd soil concentrations of 1.2–5.3 ppm depending on soil type (lowest for sandy soils, highest for silt to clay soils) should not be exceeded. Based on the Northeast guidelines (Pennsylvania State, 1985).

<sup>4</sup>The chemical form of chromium is of critical importance. Cr III is of little concern because it forms relatively insoluble compounds, but Cr VI is highly toxic and soluble. Little information is available on the ionic status of Cr in sludged soils and the potential for chromium oxidation in sludged soils. The value recommended depends on soil type (lowest for sandy soils, highest for silt to clay soils). Based on the Northeast guidelines (Pennsylvania State, 1985).

<sup>5</sup>Concentration limits aim to prevent phytotoxicity. Based on the Northeast guidelines (Pennsylvania State, 1985). 50 ppm for sandy soils, up to 150 ppm for silt to clay soils.

<sup>6</sup>The lowest attainable levels are desirable because negative effects on humans continue to be discovered at increasingly low levels. Ingestion by children is the primary concern.

<sup>7</sup>The lowest attainable levels are desirable. Ecotoxicologic and groundwater impacts are likely to be the determining factor.

<sup>8</sup>Excessive molybdenum can result in molybdenum toxicity (induced copper deficiency) in ruminants. It is recommended to test forages for molybdenum and copper periodically and to prevent ruminants from grazing on land to which sludge has been applied and not incorporated into the soil. Molybdenum is more available at higher (more basic) pH so the recommendation is for lower concentrations in more basic soils. When sludge that is high in molybdenum is applied (in excess of 10 ppm), it is recommended that forages be tested for copper and molybdenum to determine the ratio. A ratio of Cu:Mo in the diet below 4:1 may cause for concern.

<sup>9</sup>Concentration limits aim to prevent phytotoxicity. Based on the Northeast guidelines (Pennsylvania State, 1985). 30 for sandy soils, up to 60 ppm for silt to clay soils.

<sup>10</sup> Concentration limit to prevent phytotoxicity. 85 ppm for sandy soils, up to 300 ppm for silt to clay soils. Higher concentrations can be tolerated in calcareous soils.

<sup>11</sup> Based on EPA recommended soil levels (USEPA, 1996).