G1939: Crops, Waste Management
Revised July 2022

Sewage Sludge Utilization for Crop Production

Charles S. Wortmann and Javed Iqbal, Nutrient Management Specialists, Department of Agronomy and Horticulture

Municipal biosolids can provide nutrients for crop growth and improve soil productivity. A worksheet and tables address pollutant levels and how to calculate an application rate for crop production.

Treated sewage sludge, commonly referred to as biosolids, are solids, semisolids, or liquids produced during the treatment of municipal wastewater. Wastewater is processed to produce clean water for release back to streams and water bodies. Biosolids are the organic byproducts of this process. These biosolids are rich in nutrients but also may contain significant levels of contaminants such as pathogens, pollutants, and synthetic materials discharged into sewers from homes, industries, and businesses. In the past, biosolids were treated as waste products that often were incinerated or dumped in oceans or landfills.

Due to the nature of biosolids, the public is particularly attentive to concerns about odors, pollutants, and pathogens associated with land application of biosolids. Federal regulations were passed in 1993 as the Environmental Protection Agency's biosolids rule (EPA 503 Rule) to regulate land application of biosolids in order to protect human, animal and plant health, and the environment.

Environmental and Health Concerns

Municipalities have several options for meeting land application standards according to the EPA 503 Rule (Table 1). These standards depend on pathogen levels, concentrations of pollutants, and the type of treatment for reducing the attraction of vectors or carriers of pathogens (e.g., flies and rodents). In order to be land applied, all biosolids must

Table 1. Summary of options available to meet regulations for land application of biosolids[1].

Biosolids options	Pathogen class[2]	Concentration limits	Meets pollutant VAR options[3]	Type of land	Site restrictions	Tracking required
Exceptional quality	A	Yes	1–8	Any	No	No
Pollutant concentration	A	Yes	9–10	No lawns or home gardens	No	No
	B	Yes	1–10	No lawns or home gardens	Yes	No
CPLR4	A	No	1–10	No lawns or home gardens	No	Yes
	B	No	1–10	No lawns or home gardens	Yes	Yes
APLR[4]	A	No	1–8	Any	No	Yes

[1]Land-applied biosolids must meet the Ceiling Concentration Limits for Pollutants (Table 2).

[2]Class A biosolids have pathogen levels below detectable limits and have no site application or use restrictions. Class B biosolids contain a low level of pathogens, have some restrictions, and can only be handled in bulk. Biosolids produced in Nebraska are generally Class B.

[3]VAR=Vector attraction reduction. Options 1–8 are treatments done at the wastewater treatment facility such as reducing the amount of volatile solids, raising the pH under specified conditions, composting etc. Option 9 is injection of liquid biosolids into the soil during application. Option 10 is incorporation of biosolids into the soil.

[4]CPLR and APLR are the cumulative pollutant loading rate and the annual pollutant loading rate options for land application of biosolids.

Table 2. Allowable limits for pollutant concentrations of biosolids for land application.

Pollutant	Ceiling concentration limit for land application	Pollutant concentration limit for EQ and PC biosolids	Cumulative pollutant loading rate limit	Annual pollutant loading rate
	ppm on a dry weight basis		lb/A	
Arsenic	75	41	37	1.8
Cadmium	85	39	35	1.7
Copper	4,300	1,500	1,340	67.0
Lead	840	300	270	13.0
Mercury	57	17	15	0.7
Molybdenum	75	—	—	—
Nickel	420	420	375	19.0
Selenium	100	36	89	4.5
Zinc	7,500	2,800	2,500	125.0

Source: A Plain English Guide to the EPA 503 Rule.

be treated to reduce pathogen levels and all biosolids must at least meet the ceiling concentration limit for each of the pollutants listed in Table 2.

Class A biosolids have pathogen levels below detectable limits and have no site application or use restrictions (Table 1). Class A biosolids can be bagged and sold, and can be used on lawns and home gardens. If one or more of the pollutants listed by EPA 503 Rule is above the Pollutant Concentration Limit (Table 2), Class A biosolids can still be bagged, but the application rate is restricted so that the amount of the pollutant applied in one year does not exceed the Annual Pollutant Loading Rate (APLR). Bags containing APLR biosolids must be labeled with the APLR for the pollutants of concern.

Class B biosolids contain a low pathogen level and have some restrictions (Table 1). These can only be handled in bulk. Crops whose edible parts do not touch the ground can be harvested 30 days after application, but harvest of edible parts that touch the ground or are underground is restricted to 14 and 20 months, respectively. Class B biosolids have a 30-day grazing restriction and a one-year restriction on public access to public contact lands. Reporting and tracking of land application of biosolids is required if one or more of the nine pollutants is above the Pollutant Concentration Limit (Table 2). The total amount of the pollutant applied to a piece of land over time cannot exceed the Cumulative Pollutant Loading Rate (CPLR).

Biosolids produced in Nebraska are generally Class B. The ranges of pollutant values for several wastewater treatment plants in Nebraska are given in Table 3. In some cases, one or more pollutants may exceed the Pollutant Concentration Limit and tracking is required.

Table 3. The range of pollutant levels, on a dry weight basis, for biosolids of several wastewater treatment plants in Nebraska[1].

	Pollutant concentration (parts per million, ppm)	
	Low	High
Arsenic	6	16
Cadmium	2	18
Copper	245	1,660
Lead	64	98
Mercury	0.005	2
Molybdenum	7	62
Nickel	19	98
Selenium	6	32
Zinc	46	2,176

[1]The wastewater treatment plants were: the Theresa Street and the northeast plants in Lincoln; the Papillion Creek and Missouri River Valley plants in Omaha; and the treatment plants in Seward and Scottsbluff.

Agronomic Considerations

Agronomic benefits. When applied to soils, biosolids can supply nutrients and improve soil condition. Biosolids contain the full complement of nutrients required for crop growth and are a good source of nitrogen and phosphorus, the nutrients most commonly applied in Nebraska. Biosolids decompose over several years, gradually releasing nitrogen, sulfur, and micronutrients.

In addition to supplying nutrients, biosolids may improve soil organic matter, microbial activity, and soil physical properties. Effects of biosolids on soil physical properties such as increased soil aggregate formation and aggregate stability may be greater than for animal manures due to the stability of organic compounds in biosolids. Improved water infiltration may be especially valuable on upland areas where the topsoil is shallow and low in organic matter due to soil removal by erosion, grading, or terrace formation.

Nitrogen. The EPA 503 Rule states that biosolids can-

Table 4. Typical nutrient levels for biosolids of several wastewater treatment plants in Nebraska on an "as is" basis.

	Theresa Street, Lincoln	Papillion Creek, Omaha	Missouri River Valley, Omaha	Scottsbluff	Lincoln Northeast	Seward
	lb/ton				lb/1000 gal	
Dry matter	372	494	490	1766	248	224
Total nitrogen	17	20	20	88	12	11
Organic nitrogen	14	16	16	65	9	6
Ammonium-nitrogen	3	3	3	23	3	5
Phosphate	10	9	8	37	1	4
Potassium	1	1	1	9	1	1
Iron	10	13	12			

not be applied at more than the "agronomic" rate—the rate that supplies sufficient nitrogen to achieve a realistic yield goal. Most nitrogen in biosolids is in organic forms (50–85 percent) and the remaining is mostly ammonium-N (Table 4). Ammonium-N is immediately available to the crop, but much may be converted to ammonia and lost by volatilization if not incorporated into the soil (Table 5). Organic nitrogen is slowly released, typically with 40 percent available to the first crop following application and 75 percent of organic nitrogen released over four years (Table 6). The sewage treatment process influences the rate of organic nitrogen release, with slower release from more stable biosolids. When biosolids are applied at the agronomic rate, nitrogen is used as effectively as with fertilizers.

As an example, calculation of biosolids application rate, assume that 150 pounds per acre of added nitrogen is needed to achieve a realistic yield goal after giving credit for soil nitrate-nitrogen, the effects of organic matter, and other nitrogen sources. If the biosolids are immediately incorporated, biosolids from the Theresa Street Wastewater Treatment Plant in Lincoln would need to be applied at the rate of 17.4 tons per acre (Table 7). In performing such calculations, use recent analytical results from the wastewater treatment plant for ammonium and organic nitrogen, rather than the values in Table 4.

Table 5. Ammonium-nitrogen available for crop use with preplant application as affected by time to incorporation of the land-applied biosolids.

Time to incorporation or rainfall/irrigation >0.4 inch	Solid	Slurry <50 °F	Slurry ≥50 °F
Immediately	95%	95%	95%
1 day after	50%	75%	75%
2 days after	25%	55%	45%
3 days after	15%	45%	25%
>7 days after	0	40%	0%

Less of the ammonium nitrogen will be available when biosolids are applied under hot, wet, and windy conditions as compared to cold and dry conditions.

When non-legume crops are grown in the second and subsequent years, nitrogen may need to be applied to supplement the nitrogen from decomposing biosolids. Credit should be given to the release of organic nitrogen in subsequent years although actual rates of release can vary widely from the estimated rates (Table 6). Soil nitrate-nitrogen in the top 2 to 4 feet of soil and other nitrogen credits also should be considered in determining the nitrogen needs of the subsequent crop.

Phosphorus. Most phosphorus in biosolids becomes crop-available during the year of application. If biosolids are regularly applied to meet crop nitrogen needs, the supply of phosphorus will exceed crop demand. Careful planning is needed with repeated application of biosolids to avoid excessive build-up of soil phosphorus, resulting in increased potential for phosphorus loss in runoff and erosion, and contamination of surface waters. Applying 17.5 tons per acre, as in the example in Table 7, would apply 175 pounds of phosphate per acre while 45 pounds may be removed in 150 bushels of corn. Soils should be tested after three to four years to ensure adequate phosphorus availability and to avoid excessive soil phosphorus levels.

Potassium. Biosolids do not supply much potassium. Potassium is soluble and most is removed in the treated wastewater. Most Nebraska soils supply sufficient potassium for optimal crop growth, but added fertilizer potassium may be needed where soil supply is low.

Site-specific application. Crop responsiveness to applied biosolids and the potential for contamination of

Table 6. Estimated percent of organic nitrogen applied in biosolids that is crop available.

Years after application	Percent Available
0–1	40
1–2	20
2–3	10
3–4	5

surface and groundwater varies with land and soil conditions. Producers will need to weigh the costs of using biosolids against the anticipated benefits for each field, and even for zones within fields. Greater crop response to applied biosolids can be expected if: 1) soil test phosphorus is low; 2) one or more micronutrients are deficient; and/or 3) water infiltration is slow and runoff is high due to low organic matter and/or high clay content in the surface soil. The potential for environmental contamination is less if: 1) soil test phosphorus is low; 2) there is little or no chance of flooding; 3) the depth to a drinking water aquifer is more than 6.5 feet and the soil has fine texture; 4) best management practices for erosion and runoff control are applied when slope is more than 6 percent, and biosolids are not applied when slope is more than 12 percent; 5) water holding capacity is greater than 1 inch per foot of soil depth; 6) biosolids are not applied to wetlands; and/or 7) the application site is more than 100 feet from open water bodies or water flow channels. Treated effluent from a domestic wastewater treatment facility should not be applied within 500 feet of a public drinking water well, 100 feet of a private drinking water well, and 100 feet from an inhabited building.

Additional Information

A Process Design Manual: Land Application of Sewage Sludge and Domestic Septage. 1995. United States Environmental Protection Agency. http://www.epa.gov/ORD/WebPubs/landapp.pdf

Volatilization, plant uptake and mineralization of nitrogen in soils treated with sewage sludge. Technical Report 133. L. E. Sommers, C. F. Parkers, and G. J. Meyers. 1981. Water Resources Research Center, Purdue University, West Lafayette, IN.

Table 7. Calculation of application rate for biosolids, on an "as is" basis, to supply the added nitrogen needed to achieve a realistic yield goal (Steps 1 to 4), and calculation of the nitrogen supplied from the biosolids in the second year (Step 5). (Nitrogen values for biosolids from the Theresa Street Wastewater Treatment Plan in Lincoln were used for the example.)

Step 1.		
Ammonium-nitrogen in biosolids (lb per ton or 1,000 gal) (Table 4)	Ammonium-nitrogen remaining after incorporation (Table 5)	Ammonium-nitrogen available to the crop
3.0 lb/t	X 95%	= 2.85 lb/t
	X	=
Step 2.		
Organic nitrogen in biosolids (lb per ton or 1000 gal) (Table 4)	Mineralization rate of organic nitrogen (Table 6)	Organic nitrogen available to the crop
14.1 lb/t	X 40%	= 5.64 lb/t
	X	=
Step 3.		
Ammonium-nitrogen available to the crop (from Step 1)	Organic nitrogen available to the crop (from Step 2)	Total nitrogen available to the crop
2.85 lb/t	+ 5.64 lb/t	= 8.49 lb/t
	+	=
Step 4.		
Crop need for added nitrogen	Nitrogen supplied per ton	Biosolids application rate
150 lb/A	÷ 8.49 lb/t	= 17.7 t/A
	÷	=
Calculation of the nitrogen supplied from the biosolids in the second year.		
Step 5.		
50% of the organic nitrogen available in year one	Biosolids application rate	Organic nitrogen available to the crop in Year 2
5.64 lb/t / 2 (from Step 2)	X 17.7 t/A (from Step 4)	= 49.9 lb/A
	X	=

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