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Land Application of Biosolids: A Guide for POTW Operators

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LAND APPLICATION OF BIOSOLIDS
A GUIDE FOR POTW OPERATORS

Utah State University
Cooperative Extension Service

U.S. Department of Agriculture
Natural Resources Conservation Service

Utah Department of Environmental Quality
Division of Water Quality

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PURPOSE

Biosolids are a source of nutrients and organic matter that can improve the growth of crops on Utah's agricultural lands. Land application of biosolids is considered a safe and preferred alternative to landfill disposal. The U.S. Environmental Protection Agency (USEPA) regulations 40 CFR 503.14.d state "Bulk sewage sludge shall not be applied at rates above agronomic rates, with the exception of reclamation projects when authorized by the permitting authority." The Utah State Department of Environmental Quality (DEQ) has adopted USEPA regulations governing biosolids application and is the permitting authority in Utah.

Determining the rate of biosolids application is an involved process. The purpose of this document is to guide Publicly-Owned Treatment Works (POTW) plant operators through the agronomic rate calculations based on biosolids nitrogen or phosphorus content and crop nutrient requirements. These are guidelines and do not convey any rights. Refer to the biosolids permit issued to your facility by Utah DEQ for additional information and restrictions placed on land application of biosolids. POTW facilities can also obtain additional assistance from Utah State University Cooperative Extension or the USDA Natural Resources Conservation Service (USDA-NRCS). Information on contacting these agencies can be found in the government listings of your local phone directory.

Agronomic rate specifications described in this document apply to the application of Class A and Class B biosolids on areas larger than home or commercial landscapes. Typically, these will be agricultural lands, including irrigated, dryland, and range areas greater than one acre in size. Additional restrictions are placed on the application of biosolids that exceed specified pathogen and metal pollutant limits. These restrictions are summarized later in this document.

APPLICATION RATE DECISION

The rate of biosolids application is based on crop nutrient needs to ensure that excessive levels of nitrogen or phosphorus do not accumulate in soil. Excess nitrogen can cause ground water contamination while high levels of phosphorus can contaminate surface water sources. The initial biosolids application rate decision is based on the soil test phosphorus (STP) level according to Table 1. Unless heavily treated with manure or inorganic phosphorus fertilizers in recent years, agricultural fields will test lower than 100 ppm phosphorus.

Table 1. General biosolids application guidelines.

*Soil test phosphorus (STP), ppm**	*Apply biosolids based on -*
less than 50	agronomic rate for nitrogen
50 to 100	crop phosphorus removal rate
greater than 100	application not recommended

*Based on a 0 to 12 inch sample depth and sodium bicarbonate extract.

The application of biosolids to soils testing greater than 100 ppm STP may be allowed when a treatment facility owns the land receiving the biosolids. In this situation, and where the facility has the resources and ability to control runoff and obtains the appropriate permit, biosolids may continue to be applied at the agronomic rate for nitrogen. Treatment facilities applying biosolids to soils testing greater than 100 ppm STP must control runoff by diking so that no tail water leaves the application site, and minimize leaching by taking appropriate measures (e.g., water budgeting, irrigation scheduling, etc.) to prevent over-irrigation of the crop. Applicators should be aware that national regulations are being proposed to restrict application of any phosphorus source to sites with high soil test phosphorus levels.

AGRONOMIC RATE CALCULATIONS

This guide is organized to lead POTW operators through the calculations to determine agronomic rates of biosolids application. Blank copies of agronomic rate worksheets are located at the end of this guide. Remove the appropriate worksheet(s) and follow the step-by-step instructions to calculate agronomic rates based on either nitrogen or phosphorus.

The biosolids generator must collect the following information about the biosolids to calculate the agronomic rate of application:

- Percent solids or percent moisture in the biosolids
- Total kjeldahl nitrogen (TKN) content
- Ammonium nitrogen (NH_4-N) content
- Nitrate nitrogen (NO_3-N) content
- Organic nitrogen by calculation: TKN - [(NH_4-N+NO_3-N)]
- Total phosphorus content (if applications will be made on the basis of phosphorus)

A biosolids analysis can be performed by most soil and plant testing labs, and may already be included in your ongoing biosolids monitoring program. Contact a testing laboratory for more information prior to submitting biosolids samples for analysis.

The following information must be obtained from the manager of the application site:

- Crop to be grown
- Expected yield of the crop
- A recent (less than 1 year old) soil test for each field receiving biosolids. The test should include: 1) available (also called nitrate) nitrogen to a minimum depth of 2 feet; and 2) sodium bicarbonate-extractable phosphorus to a depth of 1 foot
- Any other sources of nutrients used on the fields receiving biosolids (e.g., commercial fertilizers, nutrients in irrigation waters, etc.)

A separate fact sheet has been prepared describing farmer requirements for using biosolids. You can obtain a copy of this fact sheet on the Utah State University Extension web page (www.ext.usu.edu) under the title *Land Application of Biosolids - A guide for farmers* (AG-WM-02. Share a copy of this publication well ahead of any planned application to ensure that the farmer understands the requirements, and has time to collect soil samples and provide the POTW operator with the necessary information for calculating the agronomic rate.

Nitrogen-Based Agronomic Rate (Soil Test Phosphorus < 50 ppm)

To calculate the agronomic application rate based on nitrogen refer to Worksheet 1 - *Agronomic Application Rate Summary for Nitrogen*. Photocopy the worksheet as necessary for each field. You must complete a new worksheet for each field each year biosolids are applied.

Step 1. Total available nitrogen from biosolids. Biosolids nitrogen is present in two plant available forms (ammonium and nitrate) and organic forms made available (mineralized) as biosolids decompose in soil. Worksheet 1 requires biosolids nitrogen values to be in units of kilograms per metric ton (kg/mt). Testing labs may report nitrogen concentrations in units of parts per million (ppm, common for reporting ammonium-nitrogen and nitrate-nitrogen), milligrams per kilogram (mg/kg, the same unit as ppm), or percent (%, common for reporting total kjeldahl nitrogen, or TKN). Convert all values to kg/mt *before* doing any calculations and *before* entering any values on Worksheet 1. Convert values *from* units of ppm or mg/kg *to* kg/mt according to the equation:

$$kg/mt \quad ppm \times 0.001 \quad or \quad kg/mt \quad mg/kg \times 0.001$$

Convert *from* percent *to* kg/mt according to the equation:

$$kg/mt \quad percent \times 10$$

Step 1a. Ammonium-nitrogen. Ammonium-nitrogen is adjusted for volatilization (gaseous) losses only if the material is in a liquid form and applied to the soil surface (see Table 2). Otherwise, enter the ammonium-nitrogen concentration of the biosolids in units of kg/mt in blank 1a.

Step 1b. Nitrate-nitrogen. There is assumed to be no loss of nitrate-nitrogen from biosolids after application. Enter the nitrate-nitrogen concentration of the biosolids in units of kg/mt in blank 1c.

Table 2. Volatilization factors for estimating ammonia-nitrogen loss from biosolids.*

If biosolids is:	Volatilization factor is:
Liquid and surface applied	0.50
Liquid and injected into the soil	1.00
Dewatered and applied in any manner	0.50

*Adapted from USEPA Biosolids Management Handbook Table 3.5.3.

Step 1c. First year mineralized organic nitrogen. Organic nitrogen is calculated by subtracting available (ammonium + nitrate) nitrogen from the total nitrogen content of the biosolids:

$$\textit{Organic nitrogen} \quad \textit{Total nitrogen} \quad (\textit{ammonium nitrogen} \quad \textit{nitrate nitrogen})$$

The first year organic nitrogen mineralization rate depends on the biosolids treatment process. After calculating the organic nitrogen concentration of the biosolids in kg/mt multiply by the first year mineralization factor appropriate for your biosolids treatment process (Table 3). Enter the value in blank 1b. For example, if your biosolids are anaerobically treated, the first year mineralization rate is 20% and the organic nitrogen content is multiplied by 0.20.

Table 3. Organic nitrogen mineralization rates for variously treated biosolids.*

Year	Aerobically digested biosolids	Anaerobically digested biosolids	Composted biosolids
	-------- % of initial organic nitrogen mineralized --------		
0 - 1	30	20	10
1 - 2	15	10	5
2 - 3	8	5	3
3 - 4	4	3	3
4 - 5	3	3	3

*Adapted from USEPA Biosolids Management Handbook Table 3.5.4.

Step 1d. Total available nitrogen from biosolids. Add available nitrogen from the three sources in lines 1a, 1b, and 1c and enter the value on line 1d. This is the total nitrogen available from biosolids in the first year of application.

Step 2. *Nitrogen available in the soil.* Residual soil nitrogen (nitrate-nitrogen) or available nitrogen mineralized from previous biosolids applications, in units of kilograms per hectare (kg/ha), is credited toward the nitrogen requirement of the crop.

Step 2a. Residual nitrate-nitrogen. Soil tests report residual soil nitrogen as nitrate nitrogen in units of mg/kg, parts per million (ppm), or lb/acre. For each foot of soil sampled, convert from mg/kg (or ppm) to kg/ha by multiplying by 4. If nitrate nitrogen was collected by separately sampling several feet of soil (e.g., 0-12 inch, 12-24 inch, 24-36 inch), add the individual values together and multiply the total by 4. If the report presents nitrate nitrogen in lb/acre, multiply by 1.12 to convert to kg/ha.

Step 2b. Available nitrogen from previous biosolids applications. Nitrogen continues to be released (mineralized) at progressively lower rates up to 5 years after a single application of biosolids (Table 3). If biosolids have been applied to the site in the past 5 years use Worksheet 2 (Appendix) to determine nitrogen contributions from these previous applications. *A separate Worksheet 2 must be filled out for each year biosolids are applied to the same site.*

Step 3. *Nitrogen supplied from other sources.* Enter the amount of nitrogen in kg/ha supplied from inorganic nitrogen fertilizer, irrigation waters containing nitrogen, or other sources (such as legume nitrogen credits). Few natural irrigation waters in Utah contain significant amounts of nitrogen. Effluent waters, however, may contain nitrogen and should be credited if this water is used for irrigation. Convert from ppm (or mg/liter) of nitrogen in irrigation water to kg nitrogen (N) applied/ha per foot of water according to:

$$\textit{ppm } N \times 3.0 \quad \textit{kg nitrogen/ha per acre foot of water applied}$$

Multiply the value from the above equation by the number of feet of irrigation water used during the growing season. Add the resulting value to any inorganic nitrogen fertilizer (if used) or legume contributions and enter the total on line 3.

Step 4. *Total nitrogen available from existing sources.* Add the greater value from line 2a or 2b to line 3 and enter the result here. This is the total amount of available nitrogen credited from existing sources.

Step 5. *Total nitrogen requirement of the crop.* Different crops remove different amounts of nitrogen from soil. Use the crop type and yield information supplied by the farmer, together with information from Table 4, to calculate the amount of nitrogen (N) removed by the crop. For example, a 5 ton/acre crop of grass hay would remove 150 lb N/acre (Table 4). Convert this value to kg/ha according to:

$$lb\ N/acre \times 1.12 \quad kg\ N/ha$$

For the grass hay crop described above the total amount of nitrogen removed is168 kg/ha. If a crop is not listed in Table 4, contact a local Utah State University Cooperative Extension Service or USDA-NRCS office for an estimate of nutrient removal.

Table 4. Nitrogen and phosphorus removal by common Utah crops.

Crop	Yield unit	Nitrogen (N)	Phosphorus (P)
Alfalfa	ton	45 lb/ton	6 lb/ton
Barley	bushel	1.5 lb/bushel	0.24 lb/bushel
Corn silage	ton	9 lb/ton	1.35 lb/ton
Corn grain	bushel	0.9 lb/bushel	0.16 lb/bushel
Oat hay	ton	32 lb/ton	6 lb/ton
Wheat	bushel	1.7 lb/bushel	0.31 lb/bushel
Grass hay	ton	30 lb/ton	4 lb/ton

<u>Step 6.</u> *Supplemental nitrogen needed from biosolids.* Subtract line 4 (total nitrogen available from existing sources) from line 5 (total nitrogen requirement) and enter the value here. This is the supplemental nitrogen needed from biosolids.

<u>Step 7.</u> *Agronomic application rate.* Divide line 6 by line 1d to calculate the rate of biosolids required to meet the supplemental nitrogen needs of the crop.

<u>Step 8.</u> *Adjusted application rate.* The agronomic rate calculated on line 6 is based on dry biosolids (0% moisture). The testing laboratory will also report percent dry matter or percent moisture (%moisture = 100-% dry matter) in the biosolids sample. *You must adjust the loading rate to the current moisture content of the biosolids to calculate the correct rate of application*:

$$Adjusted\ agronomic\ rate \quad \frac{dry\ agronomic\ rate}{\left(1 \quad \frac{\%\ moisture}{100}\right)}$$

<u>Step 9.</u> *Adjusted application rate in tons/acre.* The final agronomic rate calculated in step 8 is converted to tons/acre by dividing the value by 2.24. This is the application rate given to the farmer.

Phosphorus-Based Agronomic Rate (Soil Test Phosphorus = 50 to 100 ppm)

To calculate the agronomic application rate based on phosphorus refer to Worksheet 3 - *Agronomic Application Rate Summary for Phosphorus*. Photocopy the worksheet as necessary for each field.

Worksheet 3 for phosphorus is much shorter than Worksheet 1 for nitrogen. The premise of the calculations, however, is similar: phosphorus applied in the biosolids is equal to the amount of phosphorus required by the crop. Agronomic rates of biosolids according to phosphorus-based calculations will be lower than nitrogen-based agronomic rates.

<u>Step 1.</u> *Total phosphorus content of biosolids.* The total phosphorus content of biosolids is obtained from a biosolids analysis. This value must be converted to units of kg/mt before entering on line 1. See part 1 of the agronomic application rate for nitrogen for equations to convert to kg/mt.

<u>Step 2.</u> *Phosphorus supplied from other sources.* If inorganic phosphorus or phosphorus from other sources is applied to this field, enter the amount here in kg/ha. If the rate of phosphorus applied from other sources is in lb P/acre, multiply by 1.12 to convert to kg P/ha. If the rate of phosphorus applied from other sources is in lb P_2O_5/acre, multiply by 0.49 to convert to kg P/ha.

<u>Step 3.</u> *Supplemental phosphorus required by the crop.* Different crops remove different amounts of phosphorus from soil. Use soil test-based phosphorus recommendations, or crop and yield information supplied by the farmer together with information from Table 4, to determine the amount of phosphorus required by the crop. For example, a 6 ton/acre crop of alfalfa would remove 36 lb P/acre according to Table 2. Convert this value to kg P/ha according to:

$$\textit{lb P/acre} \times 1.12 \quad \textit{kg P/ha}$$

<u>Step 4.</u> *Total phosphorus needed from biosolids.* Subtract the phosphorus supplied from other sources (line 2) from the total phosphorus required by the crop (line 3) to determine the net amount of phosphorus needed from biosolids. Enter this value on line 4.

<u>Step 5.</u> *Agronomic application rate.* Divide line 4 by line 1 to calculate the agronomic application rate based on phosphorus.

<u>Step 6.</u> *Adjusted application rate.* The application rate calculated on line 5 is based on dry biosolids (0% moisture). The testing laboratory will also report % dry matter or % moisture (%moisture = 100-% dry matter) in the biosolids sample. *You must adjust the loading rate to the current moisture content of the biosolids to calculate the correct rate of application*:

$$\textit{Adjusted agronomic rate} \quad \frac{\textit{dry agronomic rate}}{\left(1 \quad \frac{\textit{\% moisture}}{100}\right)}$$

Step 7. Adjusted application rate in tons/acre. The final agronomic rate calculated in step 6 is converted to tons/acre by dividing the value by 2.24. This is the application rate given to the farmer.

ADDITIONAL CRITERIA FOR BIOSOLIDS APPLICATION

Application records that include completed worksheets, application dates, other pertinent management practices, and site restrictions must be kept.

Additional criteria for the application of biosolids are designed to minimize any environmental impacts from application. Biosolids should not be applied under the following conditions unless specific provisions are made to ensure that excess erosion, runoff, and leaching does not occur:

- Where available soil water holding capacity is less than 3 inches (very coarse textured soils);
- Where depth to bedrock or a cemented layer is less than 20 inches;
- Where the seasonal water table is less than 2 feet below the surface;
- Where flooding is frequent;
- On excessively rocky soils;
- On excessively drained soils where permeability is greater than 6.0 in/hr for solid and semi-solid applications and greater than 2.0 in/hr for liquid applications;
- Where slopes exceed 6%;
- Where the sodium adsorption ratio (SAR) exceeds 13, or soil salinity exceeds 8 deci-Siemens/meter;
- To flooded, frozen, or snow-covered ground;
- Within 30 feet of surface waters under any conditions.

Specific provisions may include considerations such as rate reductions, erosion control practices, immediate incorporation or injection, split applications, and/or limiting the number of years that biosolids can be applied. These are the same criteria that govern the application of livestock manures at agronomic rates. Contact a local USDA-NRCS or Utah State University Cooperative Extension office for information regarding soil characteristics or if you need assistance in evaluating a site for biosolids application.

ADDITIONAL RESTRICTIONS FOR CLASS B BIOSOLIDS

Restrictions are placed on the application of Class B biosolids to minimize potential health risks associated with metal contaminants:

- Cumulative and annual metal application rates cannot exceed specified limits if the concentrations of certain metals are greater than those described in column 2 (Metal Concentrations, ppm) of Table 5.

Currently, most biosolids produced in Utah are below the metal concentration limits in column 2 of Table 5. Consult the USEPA biosolids handbook or your permit for more information on metal application rates if your biosolids exceed these limits.

The following restrictions are also placed on the application of Class B biosolids to minimize potential health risks associated with pathogenic organisms:

- Food crops that have harvested parts below the soil surface (such as potatoes,

carrots) shall not be harvested for 20 months after application if biosolids have not been incorporated in the first 4 months after application. Crops shall not be harvested for 38 months if biosolids are incorporated in less than 4 months;

- Food crops that touch the soil surface (such as melons, squash) shall not be harvested for 14 months after biosolids application;
- Food crops that have harvested portions above the soil surface (such as corn), and feed and fiber crops shall not be harvested for 30 days after biosolids application;
- Animals shall not be grazed on a site for 30 days after biosolids application;
- Turf (sod) shall not be harvested for 1 year after biosolids application;
- Public access to land with high potential for public exposure shall be restricted for 1 year after biosolids application. Access to land with low potential for public exposure shall be restricted for 30 days after biosolids application.

Table 5. Metal concentrations and application rate criteria.*

Metal	Metal Concentration, ppm	Annual Application Rate, lbs/acre	Cumulative Application Rate, lbs/acre
Arsenic	41	1.8	37
Cadmium	39	1.7	35
Copper	1500	67.0	1338
Lead	300	13.0	268
Mercury	17	0.8	15
Molybdenum	--	--	--
Nickel	420	19.0	375
Selenium	100	4.5	89
Zinc	2800	125.0	2498

*Adapted from USEPA Biosolids Management Handbook.

This document is the product of a committee formed by the Utah Department of Environmental Quality, Division of Water Quality to develop biosolids application guidelines for Utah.

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WORKSHEET 1

Agronomic Application Rate Summary for Nitrogen

Field:_____
Year:_____

1. Total available nitrogen from biosolids:

a. Ammonium-nitrogen
NH_4-N (kg/mt) x Kv (see Table 2) _____ kg/mt

b. Nitrate-nitrogen _____ kg/mt

c. First year mineralized organic nitrogen
Organic N (kg/mt) x first year mineralization rate (Table 3) _____ kg/mt

d. Total available nitrogen from biosolids (add lines 1a-1c) _____ kg/mt

2. Nitrogen available in the soil (use the greater of a or b below)

a. Residual nitrate-nitrogen (from soil test results) _____ kg/ha

b. Available nitrogen from previous biosolids applications
(Use worksheet #2) _____ kg/ha

3. Nitrogen supplied from other sources
(inorganic fertilizer, irrigation water, etc.) _____ kg/ha

4. Total nitrogen available from existing sources
(Add the greater of line 2a <u>or</u> 2b and line 3) _____ kg/ha

5. Total nitrogen required by the crop
(See the soil test report or Table 4) _____ kg/ha

6. Supplemental nitrogen needed from biosolids
(Subtract line 4 from line 5) _____ kg/ha

7. Agronomic application rate
(Divide line 6 by line 1d) _____ mt/ha

8. Agronomic application rate adjusted for biosolids moisture content
(See formula in text) _____ mt/ha

9. Adjusted application rate in tons/acre (t/ac)
(Divide line 8 by 2.24) _____ t/ac

WORKSHEET 2

Calculating Mineralized Organic Nitrogen from Biosolids Applications

Field:_____
Year applied:_____

Instructions: Complete one table for each year biosolids are applied to a site. Attach this sheet to the appropriate copy of Worksheet 1.

1. Year	2. Year after application	3. Starting N (kg/ha)	4. Mineralization rate (see Table 3)	5. Mineralized organic N (kg/ha)	6. Organic N remaining (kg/ha)
	0 - 1				
	1 - 2				
	2 - 3				
	3 - 4				
	4 - 5				

*Adapted from USEPA Biosolids Management Handbook Table 3.5.1.

Steps:

Column	Description
1	Enter the calendar year on each line for biosolids organic nitrogen mineralization calculations.
2	Number of years after initial application.
3	In year 0-1, this represents the total amount of organic nitrogen initially applied. This is calculated by multiplying the biosolids organic N content (kg/mt) by the application rate in mt/ha (line 7 on worksheet 1). In subsequent years, this represents the organic nitrogen remaining from the previous year (column 6 from the previous year).
4	Nitrogen mineralization rates as a function of treatment method and year after application (see Table 3).
5	Divide the number in column 4 by 100 and multiply by column 3. In year 0-1, this number should correspond to line 1c multiplied by line 7 from Worksheet 1.
6	Subtract column 5 from column 3.

WORKSHEET 3

Agronomic Application Rate Summary for Phosphorus.

Field:_____
Year:_____

1. Total phosphorus (P) content of biosolids _____ kg/mt

2. Phosphorus (P) supplied from other sources
(inorganic fertilizer, etc.) _____ kg/ha

3. Total phosphorus (P) required by the crop _____ kg/ha

4. Supplemental phosphorus (P) needed from biosolids
(Subtract line 2 from line 3) _____ kg/ha

5. Agronomic application rate (divide line 4 by line 1) _____ mt/ha

6. Agronomic application rate adjusted for biosolids moisture content
(See formula in text) _____ mt/ha

7. Adjusted application rate in tons/acre (t/ac)
(Divide line 6 by 2.24) _____ t/ac