Water Quality

Focus Area
Nutrients & Bacterial Waste

Published by University Extension, University of Missouri-System

# Interpretation of Laboratory Analyses of Biosolids Samples

James R. Brown, School of Natural Resources, University of Missouri-Columbia
Dennis Sievers, Agricultural Engineering, University of Missouri-Columbia
Robert Magai, Environmental Specialist, Missouri Department of Natural Resources

Biosolids material is useful for land application. It contains organic matter and plant nutrients, such as nitrogen (N) and phosphorus (P).

But, biosolids material from municipal secondary waste treatment plants does not have a uniform composition. Waste characteristics and treatment technologies are different for each community. You must determine the composition of the biosolids to meet nutrient management guidelines.

## General characteristics

The biosolids dry matter content (total solids content) for land application ranges from a low of 0.5 percent to more than 50 percent. Fortunately, biosolids material from a specific plant has a narrow range in solids content over time. Each plant is designed to yield certain amounts of biosolids and effluent.

The sewage treatment facility that generates biosolids from wastewater must meet certain sampling requirements. A daily sample determines the percentage of total dry solids. In addition, each facility must sample the biosolids for chemical content. The Missouri Department of Natural Resources (DNR) dictates the sampling schedule by the volume of biosolids generated, (see MU publication WQ 423, *Monitoring Requirements for Biosolids Land Application*).

The facility submits the biosolids samples to an approved laboratory. The lab uses standard U.S. Environmental Protection Agency (EPA) and/or Missouri Department of Natural Resources (DNR) guidelines. The lab reports the analysis to the treatment facility. It is this report that is the subject of this guide.

### General information

- Name and address of biosolids source
- Date of sampling
- Name and address of the analytical laboratory
- Date of the analysis
- Signature of the analyst or lab supervisor
- Reference of methods used in analysis

### Analytical information

All parameters, except percent of solids, are measured on a dry matter basis. The preferred units of expression are milligrams constituent per kilogram dry biosolids (mg/kg).

**Required**:

| | |
|---|---|
| Total solids | Total Kjeldahl nitrogen (TKN) |
| Arsenic (As) | Total phosphorus (P) |
| Cadmium (Cd) | Lead (Pb) |
| Chromium (Cr) | Mercury (Hg) |
| Copper (Cn) | Molybdenum (Mo) |
| Zinc (Zn) | Nickel (Ni) |
| | Selenium (Se) |

Additional tests required if TKN is more than 50,000 mg/kg and/or application rate of biosolids is more than 2 dry tons per acre:
Ammonium nitrogen ($NH_4$-N)
Nitrate nitrogen ($NO_3$-N)
Organic nitrogen

**Useful:**
pH
specific gravity
Calcium (Ca) and magnesium (Mg), if lime stabilization is used.
Aluminum (Al), if alum is used in the treatment.

**Table 1. Information necessary for a complete laboratory report of the analysis of a biosolids sample.**





Printed with soy ink on recycled paper

## The laboratory report

All reports include certain information, but the format may vary. Table 1 lists the essentials found in a good report, as well as some nice-to-know facts.

## Units

The report's measuring unit should be weight of measured material per unit of total dry solids. The lab takes a volume of biosolids, weighs it, dries it and then weighs the dry material. The following is a calculation of percent of total solids (Equation I):

**Eq. I** $$\frac{\text{Weight of dry solids}}{\text{Weight of initial sample}} \times 100 = \text{percent total dry solids}$$

| Constituent | Concentration (mg/kg, dry weight) |
|---|---|
| Total Solids | 49,000 (4.9%) |
| Arsenic (As) | <5 |
| Cadmium (Cd) | 5 |
| Chromium (Cr) | 63 |
| Copper (Cu) | 709 |
| Lead (Pb) | 147 |
| Mercury (Hg) | 8 |
| Molybdenum (Mo) | 14 |
| Nickel (Ni) | 50 |
| Selenium (Se) | 4 |
| Zinc (Zn) | 1,252 |
| Total Kjeldahl Nitrogen | 45,226 |
| Organic N | 25,470 |
| Ammonium N | 19,757 |
| Nitrate N ($NO_3 - N$) | 28 |
| Total P | 19,033 |
| Total K | 3,789 |

Source: Columbia – Perche Creek Facility annual report, 1994.

**Table 2. Example of analytical information found in a laboratory report made on biosolids from a publicly owned treatment plant.**

The lab results are reported in a total dry solids measurement in one of three units — parts per million (ppm), milligrams per kilogram (mg/kg) or percent (see Table 2). These same units can also refer to an "as is" or wet weight analysis, so be sure that the lab report says "Dry Weight." Milligrams of a constituent per kilogram dry biosolids (mg/kg) is the preferred unit to use. PPM and mg/kg are numerically equal as shown in Equation II.

Other conversions are necessary, since other units may be used, (Equations II, III and IV):

- Conversion of ppm to mg/kg:

**Eq. II** $1 \text{ ppm} = 1 \text{ mg/kg}$

Note: 1 milligram (mg) = 0.001 gram and 1 kilogram (kg) = 1,000 grams

- Conversion of ppm to percent:

**Eq. III** $$\text{ppm} \times \frac{1}{10{,}000} = \%$$

- Conversion of percentage to ppm:

**Eq. IV** $\% \times 10{,}000 = \text{ppm}$

Another useful calculation is conversion of ppm or mg/kg to pounds per dry ton. A dry ton is 2,000 pound, (Equation V):

**Eq. V** $$\text{ppm} \times 0.002 = \frac{\text{lbs}}{\text{dry ton}}$$

Some laboratories report results on an as-received basis (wet basis). In such cases, the lab should also report the percentage of total solids in the sample. If the report does not specify wet or dry, contact the lab. Percentage moisture or water may be reported by some laboratories, (Equation VI):

Percent water + percent solids = 100%

Percent solids = 100% - percent water

Conversion from the as-received to the dry basis or vice-versa is easy if you know the percent total dry solids in the sample (Equation VI and VIa):

**Eq. VI** $$\frac{\%\text{ wet basis}}{\%\text{ solids}/100} = \%\text{ dry basis}$$

**Eq. VIa** $$\%\text{ dry basis} \times \frac{\%\text{ solids}}{100} = \%\text{ wet basis}$$

For example, 1 ppm of an element on the as-received (wet) basis in a sample with 5 percent total solids is:

$$1 \text{ ppm} \div \frac{5}{100} = 20 \text{ ppm dry basis}$$

The wet-to-dry conversion and its reverse calculation are important. The biosolids are applied wet, so you must calculate the quantity of wet biosolids per acre.

## Terminology

Table 1 contains the general information found in laboratory reports. There are labs that report in terms of phosphate and potash. In this case, you are not quite sure what is being reported. Likely the lab means $P_2O_5$ and $K_2O$ — the units used by the fertilizer industry to sell phosphorus and potassium fertilizers.

You may convert $P_2O_5$ percentage and $K_2O$ percentage to the preferred elemental basis (P percentage and K percentage) as follows:

Percentage $P_2O_5 \times 0.44$ = percentage P

Percentage $K_2O \times 0.83$ = percentage K

Table 2 contains a biosolids analysis. The following list explains some terms and acronyms used either on lab reports or used to modify the analytical results.

- **Total Kjeldahl Nitrogen (TKN).** This term refers to certain forms of N in the sample. Kjeldahl first developed this standard procedure. TKN usually includes organic nitrogen and ammonium-N ($NH_4$-N), but not nitrate-N ($NO_3$-N).
- **Plant Available Nitrogen (PAN).** PAN is an estimate of the fraction of applied nitrogen which is available to plants. The calculated value includes a percentage of the organic nitrogen and ammonium nitrogen, plus the nitrate nitrogen (Equation VII):

**Eq. VII** $PAN = f_o \text{ (organic N)} + f_a (NH_4\text{-N}) + NO_3\text{-N}$

The availability factors, $f_o$ and $f_a$, are necessary because all of the organic N is not plant available the first year and some of the ammonium nitrogen may volatilize.

- **Ammonium nitrogen ($NH_4$-N).** A portion of N in biosolids may be ammonium nitrogen ($NH_4$). When biosolids containing $NH_4$-N are applied to soil or crop residues, some of the $NH_4$-N may be lost by volatilization. The amount of volatilization depends upon temperature, pH of the soil and rainfall or snow, and the time period until a tillage or incorporation operation is performed. An availability factor $f_a$ (0.7) is used for surface-applied biosolids. If the biosolids are injected there is no loss, and the availability factor equals 1.
- **Nitrate nitrogen ($NO_3$-N).** The portion of total N in the nitrate ($NO_3$-N) form is soluble and not subject to direct volatilization. All $NO_3$-N in biosolids is considered plant available.
- **Organic nitrogen.** Organic nitrogen is the portion of total N in biosolids not present as NH4-N or NO3-N. Typically, 20 percent of the organic nitrogen is plant available the year the biosolids are land applied, i.e., $f_o = 0.2$. The nitrogen becomes available through mineralization by soil microbes, (see MU publication WQ 428, *Activity and Movement of Plant Nutrients and Other Trace Substances in Soils).*

# Calculations

How can the biosolids data in Table 2 relate to the plant needs on an application site? After all, nutrient management plans require a connection to plant needs. This prevents increasing soil nutrients to levels that will adversely affect ground and surface waters.

## Nitrogen

The first limit to land application of biosolids deals with nitrogen.

DNR rules state, "Annual biosolids application rates shall not exceed agronomic rates for plant nitrogen needs." The rules set up two different cases for documenting N applications.

**Case 1.** When the biosolids N content does not exceed 50,000 mg/kg (5 percent) and the biosolids application rate does not exceed 2 dry tons per acre, PAN reporting is not required.

This guideline means that up to 200 pounds of TKN per acre may be applied without further calculations:

$$2 \text{ dry tons/acre} \times \frac{2{,}000 \text{ pounds}}{\text{tons}} \times \frac{5}{100} = 200 \text{ pounds TKN/acre/year}$$

**Case 2.** In situations not covered by Case 1, report nitrogen compounds in the PAN calculations. Use University of Missouri Extension fertility guidelines to determine PAN loading and crop removal to determine agronomic rates.

For example, assume the biosolids in Table 2 are surface applied at 3 dry tons per acre.

**Step 1.** Calculate organic N concentration:

Organic N = TKN - $NH_4$-N

Organic N = 45,226 mg/kg - 19,757 mg/kg

Organic N = 25,469 mg/kg

**Step 2.** Calculate PAN:

PAN mg/kg = $f_o$ (organic N) + $f_a$ ($NH_4$-N) + $NO_3$-N

PAN mg/kg = (0.2) (25,469) + 0.7 (1,975) + 28

PAN mg/kg = 18,952 mg/kg

PAN lb./dry ton = 0.002 x 18,952 (Equation V)

PAN lb./dry ton = 38 pounds PAN/dry ton at 3 dry tons/acre

Total PAN lb./acre = 3 tons x 38 pounds/ton = 114 lb./acre

The next question that arises concerns the agronomic requirement of the crop. Refer to application requirements, MU publication WQ 430 *Crop/Nutrient Considerations for Biosolids.*

## Other Nutrients

Currently, N is the key rate to applying biosolids. Application limits depend upon PAN in the biosolids and crop removal. It is helpful to calculate the amount of other nutrients delivered by the biosolids, also.

There is no availability factor used with any elements listed in the lab report, except N. If you apply 3 dry tons per acre of the biosolids represented in Table 2, the quantity of P and K is 114 and 23, respectively:

19,033 mg/kg x 0.002 x 3 tons/acre = 114 pounds P/acre

3,789 mg/kg x 0.002 x 3 tons/acre = 23 pounds K/acre

## Pollutants

Check the metal pollutants in the biosolids to determine if any limits are exceeded. The calculation is the same as for P and K.

An example is zinc and mercury when 3 dry tons per acre of biosolids are applied (see Table 2):

1,252 mg Zn/kg x 0.002 x 3 dry tons = 7.5 pounds Zn/acre

8 mg Hg/kg x 0.002 x 3 dry tons = 0.048 pounds Hg/acre

## Application rates in gallons

The sample of biosolids represented in Table 2 has only 4.9 percent solids. It is handled as fluid from the treatment facility to the land application site. In this case, the units of measure may be gallons.

You may prefer to calculate the biosolids per 1,000 gallons, so the hauler can more easily determine the rate to apply per acre.

In the following calculations, nutrient refers to TKN, PAN, P, K and metal.

**Step 1.** Converting the concentration dry basis to wet basis (Equation VIa):

$$\text{Nutrient mg/kg dry basis} \times \frac{\%\ \text{total solids}}{100} = \text{nutrient mg/kg wet basis}$$

**Step 2.** Converting a weight of wet biosolids to gallons:

Assume the weight of a gallon of water (8.3 pounds) is the same as a gallon of biosolids (specific gravity of biosolids is assumed to equal 1):

$$\frac{1{,}000{,}000 \text{ pounds biosolids}}{8.3 \text{ pounds/gallon}} = 120{,}482 \text{ gallons biosolids}$$

This means that if a nutrient concentration in wet biosolids is 1 ppm (1 pound per 1,000,000 pounds biosolids), the concentration is 1 pound per 120,482 gallons or 0.0083 pound per 1,000 gallons. An example is:

19,757 mg $NH_4$-N/kg (see Table 2)

$$19{,}757 \times \frac{4.9}{100} \times .0083 = 8.0 \text{ pounds/1,000 gallons}$$

## Application rate in cubic feet

Biosolids with more than 20 percent total dry solids may likely be handled in cubic feet or in cubic yards. It is assumed that the specific gravity is one. Thus, one cubic foot of biosolids weighs 62.4 pounds.

For example, assume the percent solids in Table 2 is 25 percent and that we are dealing with $NH_4$-N (19,757 mg/kg dry basis):

Remember mg/kg is equal to ppm.

$$\text{mg } NH_4\text{-N/kg wet} = 19{,}757 \times \frac{25}{100} = 4{,}939 \text{ mg/kg}$$

$$\frac{4{,}939 \text{ pounds}}{1{,}000{,}000 \text{ pounds}} \times 62.4 \text{ pounds} = 0.308 \text{ pounds NH-N/cubic foot}$$

or $NH_4$-N per wet (as applied) ton could be calculated as follows:

$$19{,}757 \text{ ppm } NH_4\text{-N} \times 0.002 = 39.5 \frac{\text{lb } NH_4\text{-N}}{\text{dry ton}}$$

$$39.5 \text{ lb } NH_4\text{-N/dry ton} \times 0.75 = 29.6 \frac{\text{lb } NH_4\text{-N}}{\text{wet ton}}$$

Published with funds provided to the Missouri Department of Natural Resources from the Environmental Protection Agency, Region VII. To learn more about water quality and other natural resource issues, contact the Missouri Department of Natural Resources, P.O. Box 176, Jefferson City, MO 65102. Toll free 1-800-334-6946.

University Extension
UNIVERSITY OF MISSOURI SYSTEM
LINCOLN UNIVERSITY

■ Issued in furtherance of Cooperative Extension Work Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture. Ronald J. Turner, Director, Cooperative Extension, University of Missouri and Lincoln University, Columbia, MO 65211. ■ University Extension does not discriminate on the basis of race, color, national origin, sex, religion, age, disability or status as a Vietnam era veteran in employment or programs. ■ If you have special needs as addressed by the Americans with Disabilities Act and need this publication in an alternative format, write ADA Officer, Extension and Agricultural Information, 1-98 Agriculture Building, Columbia, MO 65211, or call (314) 882-8237. Reasonable efforts will be made to accommodate your special needs.