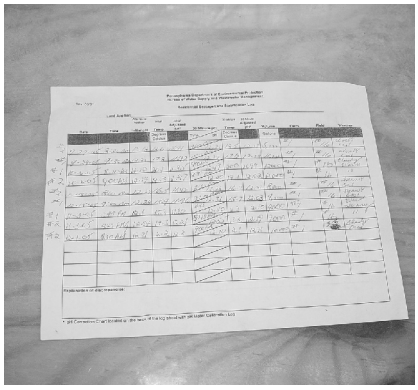
Biosolids

Sampling Manual



Commonwealth of Pennsylvania

pennsylvania
DEPARTMENT OF ENVIRONMENTAL
PROTECTION

For more information, visit DEP's website at:

www.dep.state.pa.us, keyword: biosolids

G1335-Mar13

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I. INTRODUCTION

In order to beneficially use sewage sludge within Pennsylvania, the sewage sludge must be treated and monitored to meet the state and federal biosolids quality standards for pollutants, pathogen reduction and vector attraction reduction. The intended end-use of the product will dictate the quality standards that must be met prior to beneficial use, and the amount of biosolids land applied will determine the sampling frequency for the required parameters.

In Pennsylvania, there are three categories of biosolids—Exceptional Quality (EQ), Biosolids and Residential Septage. EQ biosolids are biosolids that have achieved the highest level of treatment. Therefore, EQ biosolids can be distributed to the public with few restrictions. Examples of these products include pellets and compost. These products are often used on lawns, golf courses, athletic fields and parks.

Biosolids products do not typically meet the strict quality standards of the EQ materials. The treatment processes that produce biosolids are not specifically designed to completely eliminate all potential pathogens. Therefore, site restrictions and management practices must be used in conjunction with the treatment processes. Examples of these materials are anaerobically or aerobically digested biosolids and lime stabilized biosolids. These products are most beneficial in farming and land reclamation.

Residential septage refers to the pumpings, both liquid and solids, from septic systems or other similar treatment works that receive only residential inputs. These materials, though they can be treated to higher standards, are typically treated by lime and must be used only in conjunction with site restrictions and management practices.

To ensure that the biosolids treatment process and final product meet quality standards for beneficial use, process monitoring and sampling must be conducted on a routine basis. This sampling frequency will be dictated by the type of treatment process and amount of material generated for land application. To ensure final product quality, it is critical to establish a sampling program that is consistent and representative of the treatment process and final product.

The established sampling program must be placed in writing in the form of a sampling plan. The following information is designed to assist biosolids generators in the development of a biosolids Sampling Plan. Additional information can be found in the EPA's publication "A Plain English Guide the EPA Part 503 Biosolids Rule." http://water.epa.gov/scitech/wastetech/biosolids/503pe_index.cfm.

II. SAMPLING PLAN

What is a Sampling Plan?

A Sampling Plan is a detailed document that contains specific information related to the collection, preservation and analysis of a biosolids product to ensure compliance with the regulatory quality criteria required for biosolids distribution and land application. The Sampling Plan should be a stand-alone document that provides the person(s) collecting the samples with the necessary information to consistently collect and handle the samples in a manner that is appropriate to the tests being performed and representative of the material being tested.

The Sampling Plan should be reviewed periodically and updated as necessary to reflect any changes in the sample collection and/or treatment process. Any significant changes may require approval by Department of Environmental Protection (DEP).

Who Needs to Prepare a Sampling Plan?

Generators of biosolids products must develop a Sampling Plan if they are intending to beneficially use the biosolids under a permit issued by DEP. The Sampling Plan must be followed by all personnel collecting samples for compliance purposes and must be submitted to DEP along with the application for a general or individual permit to beneficially use biosolids by land application.

What are the Components of a Sampling Plan?

As noted above, the Sampling Plan should be a self-contained document that anyone could pick up and reasonably collect samples that are representative of the biosolids treatment process and final product to be land applied.

- **Facility Description -** As the type of treatment process can be influential in understanding wastewater flow and potential fluctuations in solids characteristics, it is necessary to have a description of the wastewater treatment and biosolids treatment processes. This would include such information as plant design flow; percentage of industrial, commercial and residential inputs; existing pretreatment programs; continuous or batch flow process; and solids handling process, including treatment design and storage activities prior to land application. A treatment diagram or flow chart should also be included to further clarify the treatment process.

- **Sample Collection and Preservation Process** – The key element of the Sampling Plan is the description of the sample collection process. Where, when and how samples are collected is crucial in ensuring samples are representative of the process and product quality. The sampling process employed will depend on the specific parameters being monitored and the facility and treatment process being evaluated. An example biosolids Sampling Plan can be found at the end of this section.

  Sample Location – The samples should be collected from a location that will yield a representative sample of the biosolids and the parameters being monitored. Since the pollutant and microbiological limits pertain to the quality of the final biosolids being land applied, the samples must be collected after the last treatment process and as close as possible to the time land application is to occur. However, time should be allotted for sample analysis results to be obtained prior to the biosolids being land applied or distributed. Samples should be taken from the same point and in the same manner for each monitoring event. The sampling location should also be safe and accessible.

  Collection Method – The sampling technique varies depending on whether the biosolids are flowing through pipes, moving on a conveyor or stored in a pile or bin. Biosolids that are transported through pipes or on a conveyor should be sampled at equal intervals during the time the unit operates in a day. When sampling from piles or bins, core samples should be taken from a minimum of seven points and at varying depths in the pile or bin.

  When determining whether a sample should be collected using a single grab or composite sampling method, the following factors should be considered:

  - How well are the biosolids mixed?
  - Are the samples collected from a single batch of biosolids or from a stockpile made up of several batches?
  - Does the biosolids characteristics vary over time?

In general, compositing several samples may provide a more representative sample than collecting one grab sample. Therefore, in most situations, composite samples should be performed.

Samples should always be collected using the appropriate equipment. It is recommended to use clean and/or sterile stainless steel containers and sampling devices for retrieving and mixing samples. When taking multiple samples to form a composite sample, it is important to thoroughly mix the solids prior to removing a sample for analysis. The sample must be sent to the laboratory in the proper storage container as recommended in the particular analytical method. Sample delivery should also follow quality assurance protocols related to chain-of-custody.

Number of Samples - Although 25 Pa. Code §271.917 of DEP's municipal waste regulations establishes the monitoring frequency for biosolids land applied under the current regulations, it does not specify the specific number of samples to collect per sampling event. Therefore, DEP suggests using U.S. Environmental Protection Agency's (EPA's) recommendation that a minimum of seven samples be collected for each sampling event. This could mean collecting seven individual grab samples that are mixed together to form a single composite sample or seven distinct grab or composite grab samples that are analyzed separately. Ultimately the number of samples necessary to represent the quality of the biosolids will depend on the nature of the treatment and solids handling processes and the amount of biosolids being land applied.

In general, the more samples that are taken, the more representative the sampling results will be for a particular facility.

Preservation - Appropriate preservation techniques ensure that a sample remains representative for the period it is held prior to being analyzed. For field and laboratory biosolids samples, cooling to 4^{o}C is typically the most appropriate preservation method. Samples should be kept at 4˚C until the analyses are performed.

Sampling Event -- For the purposes of this manual, a sampling event is defined as a minimum of seven individual samples to be collected and analyzed for the parameters (i.e., enteric viruses, viable Helminth ova, percentage of solids, temperature, pH, volatile solids, etc.,) that are used at the facility, to meet the pollutant, pathogen and vector attraction reduction requirements.

Analytical Methods – The Sampling Plan must include a list of the analytical methods for each parameter monitored for compliance purposes. In addition, the Sampling Plan must include the name and contact information for the laboratory performing the analyses. All analyses of biosolids for land application performed to show compliance with the regulatory requirements must be conducted using the methods specified in 25 Pa. Code §271.906 (b) of DEP's municipal waste regulations or any amendments published in the *Federal Register*, whichever is the latest. A list of methods is also contained in Appendix C of this manual. Other methods may be approved, therefore this is not an inclusive list.

It is important to contact the laboratory being used for analyses to:

- Verify the analytical methods being used
- Ensure that they can run the analyses with detection limits (or the lowest limit of detection of a particular constituent) that are below the individual regulatory levels
- Verify that they will report the analyses results in the correct unit measurement (eg, mg/kg)
- Determine the correct container to be used for the constituent being analyzed (eg, PCBs should only be collected in glass containers)
- Determine the appropriate preservation and holding times for the samples prior to analysis (e.g., biological samples require relatively short holding times prior to analysis compared to pollutant samples)

Laboratory Accreditation - All environmental laboratories conducting testing and analysis of drinking water, nonpotable water and/or solid and chemical materials for compliance with any of the 12 statutes listed in Chapter 252(Environmental Laboratory Accreditation) or DEP's general health and safety regulations including The Clean Streams Law and Solid Waste Management Act, must register with DEP and receive Pennsylvania accreditation.

Regulations pertaining to environmental laboratory accreditation were published in the Jan. 28, 2006 *Pennsylvania Bulletin*. These regulations were promulgated under 25 PA Code Chapter 252.

Registration – All environmental laboratories, including laboratories accredited-by-rule, must register with DEP. This would include all wastewater treatment facilities, biosolids processing facilities and septage haulers that are conducting testing for compliance purposes. It requires the submittal of a registration form and one-time fee of $50.

Accredited-by-rule (ABR) – Environmental laboratories that are performing testing limited to the constituents listed in §252.6(f) and listed below can be accredited-by-rule for those constituents as outlined in §252.6.

Septage haulers conducting pH and temperature measurements would be considered ABR. However, septage haulers must still register with DEP.

List of 252.6(f) ABR Constituents:

- Alkalinity
- Carbon dioxide
- Color
- Dissolved oxygen
- Field radioactivity using hand held-survey instruments
- Flash point and total halogen determination on waste oil by a waste oil transporter or waste oil transfer facility as required by 298.44
- Flow
- Foam
- Hardness
- Odor
- Oxidation-reduction potential
- Paint filter test
- pH
- Residual disinfectant concentration
- Settleable solids
- Sheen
- Sludge volume index
- Specific gravity
- Sulfite
- Taste
- Temperature
- Turbidity
- Vapor analysis using hand-held survey instruments
- Volatile acids in wastewater and sludge

More information relating to environmental laboratory accreditation can be found on DEP's website at www.dep.state.pa.us, keyword: Lab Certification.

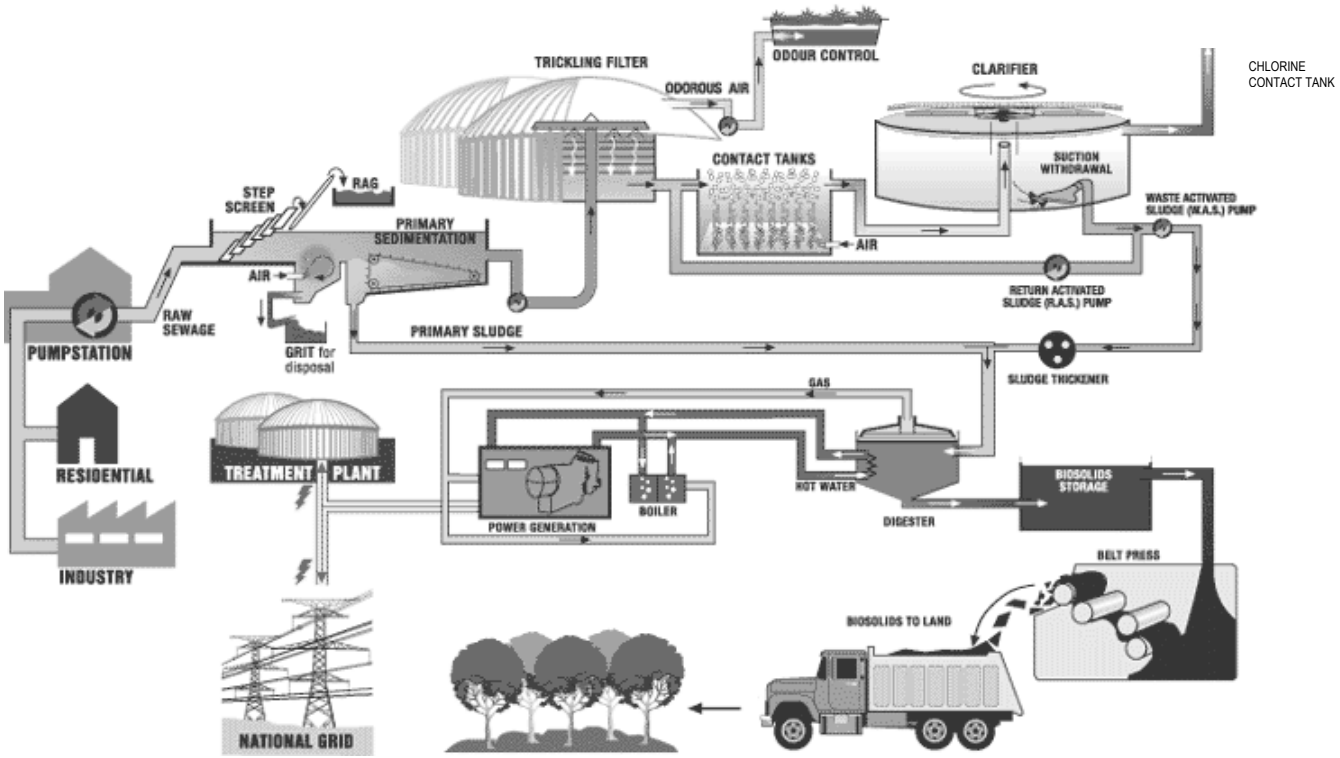
EXAMPLE

BIOSOLIDS SAMPLING PLAN

Treatment Plant Description

The Lucky Wastewater Treatment Plant (WWTP) is located at 10 Treatment Plant Road in Your Town, Pennsylvania. The plant encompasses about seven acres.

The WWTP is under continuous operation to treat incoming wastewater prior to effluent discharge to Crystal River. The majority of wastewater influent is domestic, with only about 2.7 to 3 percent of the daily flow coming from pretreated industrial sources. Biosolids are produced constantly during this process; all biosolids produced are stabilized via anaerobic digestion.



Sewage Treatment Process

The wastewater treatment process includes a step screen at the headworks, grit removal, primary sedimentation, trickling filters, contact tanks, secondary clarification and chlorination for disinfection. The receiving stream is Crystal River. Waste activated sludge and primary sludge are mixed and fed to an anaerobic digester for stabilization.

The digested biosolids are then transferred to a secondary digester for storage until dewatered. The stabilized biosolids are dewatered using polymer and three belt filter presses. The dewatered biosolids are conveyed directly to the transportation vehicle and transported to the land application site.

Pathogen Reduction

Class B Alternative 2 pathogen reduction requirements are met by maintaining a minimum mean cell residence time (MCRT) in the digester of 15 days with temperatures at 35 to 55 degrees Celsius (95°F to 131°F). The MCRT is calculated on a weekly basis using the following formula.

Anaerobic Digester Mean Cell Residence Time (MCRT):

Digester Dimensions = 65' diameter, 30' side water height with overflow at 28.5'
Operate at 2' below overflow, so tank height is 26.5'
Floor is sloped and is 6' feet deep at cone center

Digester Volume (ft^3) = $(0.785 \times D^2 \times H)$
$(0.785 \times (65)^2 \times 26.5) + \{(0.785 \times (65)^2 \times 6)/3\} = 94{,}524\ ft^3$

Digester Volume (Gal) = $(ft^3 \times 7.48) = 94{,}524 \times 7.48 = 707{,}039$ Gallons

MCRT = Digester Volume (Gal) / Total Primary Gallons Wasted + Total Thickened Gallons Wasted

Total Primary Gallons Wasted = Total Gallons from all four Primary Tanks

Total Thickened Gallons Wasted = {MLSS x MLSS Waste Sludge (MGD) / %Total Solids DAF (as decimal)}

MLSS = Average MLSS from both Aeration Basins
MLSS Waste Sludge (MGD) = MLSS Waste Sludge (GPD) / 1,000,000
Percent Total Solids (as decimal) = Percent Total Solids / 100

Temperature:

Temperature readings are taken twice per day at the circulator pump. The temperatures must read 35 to 55 degrees Celsius (95°F to 131°F).

Vector Attraction Reduction

Vector Attraction reduction is achieved through Option 1, which states that the mass of volatile solids (VS) in the sewage sludge must be reduced by at least 38 percent. The percent VS reduction is calculated twice a week using the standard Van Kleeck equation. The percent VS from the sludge well and the percent VS from the secondary digester are used to calculate the digester percent VS reduction.

Percent Volatile Solids Reduction:

$$\text{Percent VS Reduction} = \frac{\%VS_{(\text{sludge well})} - \%VS_{(\text{sec digester})} \times 100}{\%VS_{(\text{sludge well})} - [\%VS_{(\text{sludge well})} \times \%VS_{(\text{sec digester})}]}$$

Pollutants

Representative sampling of the anaerobically digested biosolids is conducted by a subcontractor on a quarterly schedule. This is the required minimum monitoring frequency based upon annual biosolids production for land application. The WWTP occasionally samples the biosolids more frequently and has the samples analyzed at either ABC Associates, Inc. (PA Lab ID # XXXXX) or DEF Labs (PA Lab ID #XXXXX). The quarterly representative biosolids sample is collected by taking seven equal volume grab samples of the finished biosolids. The biosolids samples are collected off the belt while the dewatering is in process. The grab samples are collected using a clean stainless steel trowel and placed in a clean stainless steel container until the end of the day. These grab samples are then mixed thoroughly into one composite sample. The composite sample is sealed in an appropriate sample container and shipped on ice (4°C) to the following lab:

XYZ Laboratories, Inc.
4444 Anywhere Road
Mytown, VA 23224
Contact: John Smith
555-555-1212

PA Accreditation ID Number: XXXXXXX
PA Lab Registration Number: XXXXXXX

The laboratory analyzes the biosolids for the following parameters:

SM 2540G	Solids
EPA 351.3	Nitrogen (TKN)
EPA 350.2	Ammonia-N
SM 4500-NO_3F	NO_3-NO_2-N
SW 846-6010B	Aluminum
SW 846-7061A	Arsenic
SW 846-6010B	Cadmium
SW 846-6010B	Calcium
AOAC 955.01	Calcium Carbonate Equivalency
SW 846-6010B	Chromium
SW 846-6010B	Copper
SW 846-6010B	Iron
SW 846-6010B	Lead
SW 846-6010B	Magnesium
SW 846-6010B	Molybdenum
SW 846-6010B	Nickel
SW 846-6010B	Potassium
SW 846-7741A	Selenium
SW 846-6010B	Sodium
SW 846-6010B	Sulfur
SW 846-6010B	Zinc
SW 846-6010B	Phosphorus
SW 846-7471A	Mercury
EPA 150.1	pH

GHI Corporation (PA LAB ID # XXXXX) of Mytown, Va., has performed the Poly-Chlorinated Biphenyl (PCB) testing according to SW846 Method 8082. Toxicity Characteristic Leaching Procedure (TCLP), to determine if the biosolids are a hazardous waste, has been conducted by JKL, Inc. (PA Lab ID # XXXXX) of Yourplace, Ohio.

No biosolids are stored for or at the plant for greater than 30 days. Biosolids are trucked from the facility at regular intervals to either a land application site or to the landfill.

III. Permit Application Submittal

When submitting an application for a beneficial use permit, sufficient data must be submitted in order to determine that the biosolids meet the regulatory quality criteria. The following section describes the required amount of sampling information to be provided with a permit application. The amount of information will be dependent on whether or not the applicant currently has a beneficial use program.

Generators that have an existing biosolids land application program:

Biosolids generators that have analytical data readily available on the quality of the biosolids being generated, must submit the available previous three years analytical results with their biosolids application. These laboratory results must demonstrate that the regulatory requirements for pollutants, pathogen reduction and vector attraction reduction have been and are currently being met.

If analytical results for one or more of the required parameters are not available, one of the following steps should be taken:

- If analytical results for parameters in either Table 1 or Table 3 of §271.914 (b) of DEP's municipal waste regulations are needed, laboratory results for a weight-composite sample from at least one sample event should be provided to DEP.

- If analytical results with respect to pathogen reduction (i.e., enteric viruses, viable helminth ova, fecal coliform or salmonella sp. bacteria, pH, etc.) are needed, analytical results from a minimum of two sampling events showing at least 60 days of biosolids generation are required to be submitted to DEP with the application. Laboratory results for these parameters must be below specified levels in accordance with the specific requirement for the pathogen treatment process used at the facility. Process control records, showing at least 60-days of biosolids generation, (i.e. time, temperature, etc.) may also be required depending on the pathogen reduction alternative selected.

- If analytical results with respect to vector attraction reductions (i.e., volatile solids, temperature, percent solids, pH, etc.,) are needed, analytical results for a minimum of two sampling events showing at least 60-days worth of the biosolids generation are required to be submitted to DEP with the permit application. Laboratory results for the parameters must meet the specific requirements in accordance with the vector attraction reduction treatment process used at the facility. Process control records, showing at least 60 days of biosolids generation, (i.e. time, temperature, etc.) may also be required depending on the vector attraction reduction option selected.

Generators of biosolids from new facilities without a land application program:

Generators of biosolids from new facilities without any analytical data available must submit results of samples for a minimum of two sampling events showing at least 60-days worth of the biosolids generation. Laboratory results must demonstrate that the facility can meet the requirements for pollutants, pathogens and vector attraction reduction. Process control records, showing at least 60 days of biosolids generation, (i.e. time, temperature, etc.) may also be required depending on the pathogen reduction alternative and vector attraction reduction option selected.

Hazardous Waste Determination

In addition, the applicant must also submit evidence that a "Hazardous Waste Determination" has been conducted in accordance with requirements specified in 40 CFR 262.11(c), to the extent incorporated by reference in Title 25 Pa. Code §262a.10 of DEP's Hazardous Waste Management Regulations. This may be one of the following:

- Laboratory analysis of the biosolids conducted in accordance with 40 CFR 261.24.
- A report of industrial wastes discharged into the sewer system such as the one included in the annual report required in Title 25 Pa. Code §94.12.
- If the data in items 1 and 2 above are unavailable, the signed certification in Appendix 1 that the biosolids are not hazardous.

IV. REGULATORY QUALITY CRITERIA

In order to beneficially reuse biosolids in Pennsylvania, the final products must be treated and monitored to ensure that the pollutant, vector attraction reduction (VAR) and pathogen reduction standards are met. The classification of the final biosolids product will be determined based on which of these parameters can be met. This section will review the regulatory requirements and discuss the monitoring frequency for each of the three quality criteria.

Pollutant Limits

Pennsylvania's pollutant limitations, including ceiling concentrations and pollutant concentrations, can be found in §271.914 of DEP's municipal waste regulations.

All biosolids, except residential septage, intended for land application must meet the Table 1 Ceiling Concentrations listed in §271.914(b)(1). These concentrations are expressed as milligrams of pollutant per kilogram of biosolids on a dry weight basis. These limits are instantaneous values, which means that all biosolids samples analyzed must meet the established limits.

TABLE 1 – CEILING CONCENTRATIONS

Pollutant	Ceiling Concentration (mg/kg)[1]
Arsenic	75
Cadmium	85
Copper	4,300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
PCBs	8.6
Selenium	100
Zinc	7,500

[1] Dry-weight basis

When biosolids are to be distributed as EQ, meaning they are to be sold or given away in a bag or other container, then the biosolids must meet both the Table 1 values and the pollutant concentrations listed in §271.914(b)(3) prior to distribution. Unlike the ceiling concentrations, the pollutant concentrations are monthly averages. This means that the arithmetic average of all analyses collected and analyzed during the month must be used for each parameter to determine compliance.

TABLE 3 – POLLUTANT CONCENTRATIONS	
Pollutant	**Monthly Average Concentrations (mg/kg)[1]**
Arsenic	41
Cadmium	39
Copper	1,500
Lead	300
Mercury	17
Molybdenum	NA
Nickel	420
PCBs	4
Selenium	100
Zinc	2,800

[1] Dry weight basis
NA = not applicable

Residential septage intended for land application does not have to be monitored for pollutants. Historical data has shown that septage is consistently low in pollutants and hence does not warrant continuous monitoring.

POLLUTANT SUMMARY

- **Biosolids** – Must meet Table 1 Ceiling Concentrations
- **Exceptional Quality Biosolids** – Must meet both the Table 1 Ceiling Concentrations and Table 3 Pollutant Concentrations
- **Residential Septage** – Not required to be monitored for pollutants

Vector Attraction Reduction

Vector attraction is the characteristic of sewage sludge that attracts rodents, flies, mosquitoes or other organisms capable of transporting infectious agents.

The interaction between vectors and humans provides a potential pathway for the transmission of disease. Vectors themselves are not pathogenic. Examples of vectors include flies, mosquitoes and rodents.

In general, raw sewage sludge contains organic materials that are a desirable food source for certain vectors. The vector attraction reduction requirements are designed to reduce this potential food source or to place a barrier (e.g. soil) between the biosolids and the vector.

The 11 approved VAR options are located in §271.933(b)(1)-(11) of DEP's municipal waste regulations and are summarized in the following table.

VAR Options	
Option	**Process Requirements**
1	The mass of volatile solids shall be reduced by a minimum of 38 percent.
2	When the 38 percent volatile solids reduction requirement in Option 1 cannot be met for **anaerobically** digested biosolids, VAR can be demonstrated by **anaerobically** digesting a portion of the previously digested biosolids in a bench-scale unit for an additional 40 days at temperatures between 86°F and 98°F (30°C and 37°C). VAR is achieved if the biosolids are reduced by ≤17 percent at the end of the 40 days.
3	When the 38 percent volatile solids reduction requirement in Option 1 cannot be met for **aerobically** digested biosolids, VAR can be demonstrated by **aerobically** digesting a portion of the previously digested biosolids that is ≤2 percent solids in a bench-scale unit for an additional 30 days at 68°F (20°C). VAR is achieved if the biosolids are reduced by ≤15 percent at the end of the 30 days.
4	The SOUR (specific oxygen uptake rate) for an aerobic process shall be ≤1.5 milligrams of oxygen per hour per gram of total solids (dry weight) at a temperature of 68°F (20°C).
5	The sewage sludge shall be treated in an aerobic process for 14 days or longer during which time the temperature shall be higher than 104°F (40°C) and the average temperature of the sludge shall be higher than 113°F (45°C).
6	The pH of the sewage sludge shall be raised to 12 or higher by alkali addition and, without adding more alkali, shall remain at 12 or higher for 2 hours and then at 11.5 or higher for an additional 22 hours.
7	The percent solids of sewage sludge that does not contain unstabilized solids generated in a primary wastewater treatment process shall be equal to or greater than 75 percent based on the moisture content and total solids prior to mixing with other materials.
8	The percent solids of the sewage sludge that contains unstabilized solids generated in a primary wastewater treatment process shall be equal to or greater than 90 percent based on the moisture content and total solids prior to mixing with other materials.
9	Sewage sludge shall be injected below the surface of the land. No significant amount of the sewage sludge may be present on the surface one hour after injection. When sewage sludge meets the Class A pathogen requirements, the sewage sludge shall be injected within 8 hours after being discharged from the treatment process.
10	Sewage sludge applied to the land shall be incorporated into the soil within six hours after application. When sewage sludge meets the Class A pathogen requirements, the sewage sludge shall be incorporated within eight hours after being discharged from the treatment process.
11	The pH of residential septage shall be raised to 12 or higher by alkali addition and, without the addition of more alkali, shall remain at 12 or higher for 30 minutes.

NOTE: EQ biosolids must meet one of the Class A pathogen reduction alternatives **prior to or at the same time** as one of first eight vector attraction reduction options**.**

Option 1 – 38 Percent Volatile Solids Reduction

This VAR option requires that the mass of volatile solids in the biosolids be reduced by a minimum of 38 percent. This is typically achieved through anaerobic or aerobic digestion. Volatile solids are calculated across digestion facilities so the starting point for measuring volatile solids is where the solids mass first enters the solids treatment process and the endpoint is at the final point of discharge. However, credit is not given to any volatile solids destruction that occurs during the wastewater treatment process prior to solids handling.

The percent volatile solids reduction is calculated using one of three formulas—full mass balance, approximate mass balance, or Van Kleeck. Detailed information on the appropriate use of each of these formulas is provided in the latest version of the EPA's document, *Control of Pathogens and Vector Attraction in Sewage Sludge*, (EPA/625/R-92/013) more commonly referred to as the "White House Document." The Van Kleeck method is the most commonly used formula as it is the least complicated and most conservative. However, it is not necessarily appropriate in all situations. Please refer to the White House Document to determine which method is best for your particular facility.

Option 2 – Anaerobic Digestion: Less than 17 Percent Volatile Solids Reduction

VAR Option 2 is used when a facility uses anaerobic digestion, but is unable to verify compliance with the 38 percent reduction requirement of Option 1. This often occurs when the sewage sludge entering the digester has already achieved substantial volatile solids reduction through the initial wastewater treatment process. In cases like this, it is necessary to demonstrate using a bench scale unit that volatile solids reduction in the sewage sludge will not be reduced by any more than 17 percent over 40 additional days of digestion at a temperature between 30°C and 37°C. If the volatile solids reduction is less than 17 percent after the additional digestion, then VAR has been achieved.

Option 3 – Aerobic Digestion: Less than 15 Percent Volatile Solids Reduction

This option is similar to Option 2 in that it is used when the 38 percent volatile solids reduction cannot be achieved due to the treatment of the sewage sludge during wastewater treatment. However, this option is specific to aerobic digestion. To demonstrate compliance with Option 3, a sample of the aerobically digested sludge that is 2 percent solids or less must be treated further in a bench scale unit for 30 additional days. Liquid sludges that are greater than two percent solids can be diluted using unchlorinated effluent prior to running the test. At the end of the 30 days, the volatile solids reduction must be less than 15 percent to meet VAR.

Option 4 – SOUR Test

Option 4 provides another way to demonstrate VAR for aerobically digested sewage sludge. Compliance is demonstrated if the specific oxygen uptake rate (SOUR) of the sewage sludge is equal to or less than 1.5 milligrams of oxygen per hour per gram of total solids (dry weight basis) at 20°C (68°F).

The SOUR test can only be conducted on aerobically digested sewage sludge that is equal to or less than two percent solids and that has not been deprived of oxygen for more than two hours. Liquid sludges that are greater than two percent solids, but are equal to or less than four percent, can be diluted using unchlorinated effluent prior to running the test. Therefore, this test is not applicable to dewatered sludge, compost or anaerobically digested sludge.

Note: DEP has developed a computer program to assist in determining compliance using the SOUR test. This program can be found on DEP's website using the link found on the back of this manual.

Option 5 – Aerobic Processes Greater than 40ºC

This VAR option primarily applies to composting; however, other aerobic treatment processes can utilize this option as long as the time-temperature regime can be met. In order to comply with Option 5, the sewage sludge must be treated in an aerobic environment for 14 days with temperatures reaching greater than 40ºC (104ºF) and having an average temperature higher than 45ºC (113ºF). It is typically easier to use Options 1, 3 or 4 when treating sewage sludge by traditional aerobic digestion.

Option 6 – Alkali Stabilization

The addition of alkali substances causes an increase in pH that effectively decreases biological activity and subsequently reduces the breakdown of the sewage sludge making the resulting biosolids less attractive to vectors. This is not, however, permanent. If the pH of the biosolids decreases, biological activity can be reestablished and make the material attractive to vectors.

To meet the VAR standards for this option, the pH must be raised to 12 and maintained at 12 for two hours and 11.5 for an additional 22 hours without adding more alkali. The pH measurements must be conducted in a slurry at either 25ºC or adjusted to 25ºC by using the following formula:

pH at 25ºC = Measured pH + Correction Factor

Temperature correction must be conducted unless the sample is evaluated at 25ºC and can only be calculated if using a temperature compensating probe. Temperature compensated probes only correct for variations in the conductance. Essentially, the meter is adjusted to read the actual pH at the actual temperature of the slurry. It does not provide a pH that is corrected back to the 25ºC required regulatory standard. If a temperature compensating meter is not used, then the sample must be measured at 25ºC. Appendix A of this manual contains information relating to pH measurement as well as a pH correction chart containing correction factor values.

Logs must be kept documenting the pH, temperature, and temperature corrected pH. Current DEP lime stabilization logs can be found online in DEP's eLibrary.

Option 7: Moisture Reduction of Sewage Sludge Containing No Unstabilized Solids

VAR is considered to be met under this option if the final solids content of the biosolids is greater than or equal to 75 percent and it does not contain unstabilized solids generated during primary wastewater treatment. The 75 percent solids requirement must be met by removal of water and not be addition of inert substances.

Option 8: Moisture Reduction of Sewage Sludge Containing Unstabilized Solids

Under this option, the biosolids must have a solids content of 90 percent or greater. Again, as with Option 7, this must be accomplished by the removal of water and not by adding solids. Since unstabilized solids may be present, the dessication process is necessary to limit biological activity and decomposition that could attract vectors.

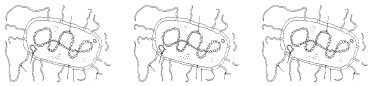
Option 9 and 10: Barrier Methods (Injection and Incorporation respectively)

The biosolids are either injected into the soil or turned under to provide a barrier between the biosolids and potential vectors. These options are used when one of the process-oriented options cannot be met.

Because it is not feasible to inject or incorporate biosolids that are applied to lawns, home gardens, or is sold, given away in a bag or other container, EQ biosolids cannot utilize this option.

Option 11: Alkali Stabilization of Residential Septage

This option is only for residential septage. Enough alkali must be added to the septage to raise and hold the pH at 12 for 30 minutes without the addition of more alkali. As with Option 6, the pH must either be evaluated at 25ºC or temperature corrected to 25ºC when using a temperature compensating meter. See Option 6 for the proper formula. Each batch of septage must be monitored for pH. Logs must be kept documenting the pH, temperature and temperature-corrected pH.



Pathogen Reduction

Pathogens are organisms capable of causing disease. These include certain bacteria, fungi, viruses, protozoa (and their cysts) and intestinal parasites (and their ova).

Because sewage sludge can contain various pathogens, it must be treated to significantly reduce or eliminate these pathogens prior to beneficial use. The level of pathogen reduction determines whether the biosolids are classified as either Class A or Class B and subsequently the level of restrictions placed on how the final product can be used. The different pathogen reduction alternatives can be found under §271.932 and are described below.

Class A Alternatives

Biosolids that are applied to lawns, gardens or that are otherwise provided to the general public must be treated to eliminate the risk of disease transmission to the public. Because it is not feasible to impose site restrictions in these situations, the biosolids must meet the most stringent, Class A pathogen reduction requirements. Commonly used Class A treatment technologies include composting and heat drying. The various Class A pathogen reduction treatment alternatives can be found in §271.932 and are revisited below.

IMPORTANT NOTE

***ALL* the Class A pathogen reduction alternatives require final product sampling for either fecal coliform or Salmonella sp. *AND* process control and/or microbiological monitoring (i.e. enteric virus and Helminth ova) for the associated technology.**

- **Salmonella sp. < 3 MPN per 4 grams of total solids (dry weight)**
- **Fecal coliform < 1000 most probable number (MPN) per gram of total solids (dry weight)**

Note: *The requirements given are per sample analysis result. Analysis results may not be averaged to meet this requirement.*

Alternative 1: Thermal Treatment

This alternative is used when the treatment process meets specific time-temperature regimes necessary to reduce pathogens below detection. There are four different time-temperature regimes provided in this alternative based on the percent solids of the sewage sludge and operating parameters of the treatment process. This alternative is not suitable for compost. The appropriate time-temperature regime for composting is specified in Alternative 5.

Regime	Applicability	Time-temperature Requirements*
A	Percent solids ≥7 percent (except for sewage sludge covered by Regime B)	T≥ 122°F (50°C); D≥ 0.0139 (ie. 20 minutes); and time-temperature shall be determined as follows: $\frac{D = 131,700,000}{10^{0.1400T}}$
B	Percent solids ≥ 7 percent and small particles of sewage sludge are heated by warmed gases or an immiscible liquid	T≥ 122°F (50°C); D≥ 1.74×10^{-4} (ie. 15 seconds); and time-temperature shall be determined as follows: $\frac{D = 131,700,000}{10^{0.1400T}}$
C	Percent solids is < 7 percent and treatment time is at least 15 seconds but less than 30 minutes.	$\frac{D = 131,700,000}{10^{0.1400T}}$
D	Percent solids < 7 percent; temperature is ≥ 122°F (50°C); and the contact time is ≥ 30 minutes.	$\frac{D = 50,070,000}{10^{0.1400T}}$
* T = Temperature in degrees Celsius (°C) D = Contact time in days		

Alternative 2: High pH-High Temperature Treatment Process

In order to meet Class A pathogen reduction standards under this alternative, the sewage sludge must be treated in a high pH, high temperature and low moisture environment. The process requirements are listed below.

- ❖ Elevate and maintain a pH above 12 for 72 hours
- ❖ Maintain temperature above 125 °F (52°C) for 12 hours or longer during the same period that the pH is above 12.
- ❖ Air dry to greater than 50 percent solids after the 72 hours of elevated pH

Using a calibrated pH meter, the pH should be measured at 25^{o}C (77^{o}F) or at the existing temperature and corrected to 25^{o}C when using a temperature compensating meter. Refer to Appendix A of this manual for further information on how to measure pH, calibrate a pH meter and compensate for temperature.

Alternative 3: Treatment by Other Processes

This alternative is used when treating sewage sludge by a process that does not fit the process requirements under Alternatives 1, 2 or 5. The biosolids must be analyzed directly for helminth ova and enteric viruses before and after pathogen treatment.

Indicator Organism	Test Result	Outcome
Fecal Coliform or Salmonella sp.	Fecal coliform at time biosolids are used is < 1,000 MPN / gram TS (dry weight) Salmonella sp. at time biosolids are used is < 3 MPN / 4 grams TS (dry weight)	Class A until next monitoring event as long as the biosolids also meet the enteric virus and Helminth ova standards.
AND		
Enteric Virus	Density prior to treatment is < 1 PFU / 4 grams TS (dry weight)	Class A with respect to enteric virus until next monitoring event.
Enteric Virus	Density prior to treatment is ≥1 PFU / 4 grams TS (dry weight)	Class A with respect to viruses if after treatment the density is reduced to < 1 PFU / 4 grams TS **AND** process operating parameters are documented. Class A with respect to viruses until next monitoring event as long as operating parameters remain in the range documented.
Helminth ova	Density prior to treatment is < 1 viable ova / 4 grams of TS (dry weight)	Class A with respect to Helminth ova until the next monitoring event.
Helminth ova	Density prior to treatment is ≥ 1 viable ova / 4 grams of TS (dry weight)	Class A with respect to Helminth ova if after treatment the density is reduced to < 1 viable ova / 4 grams TS **AND** process operating parameters are documented. Class A with respect to Helminth ova until next monitoring event as long as operating parameters remain in the range documented.

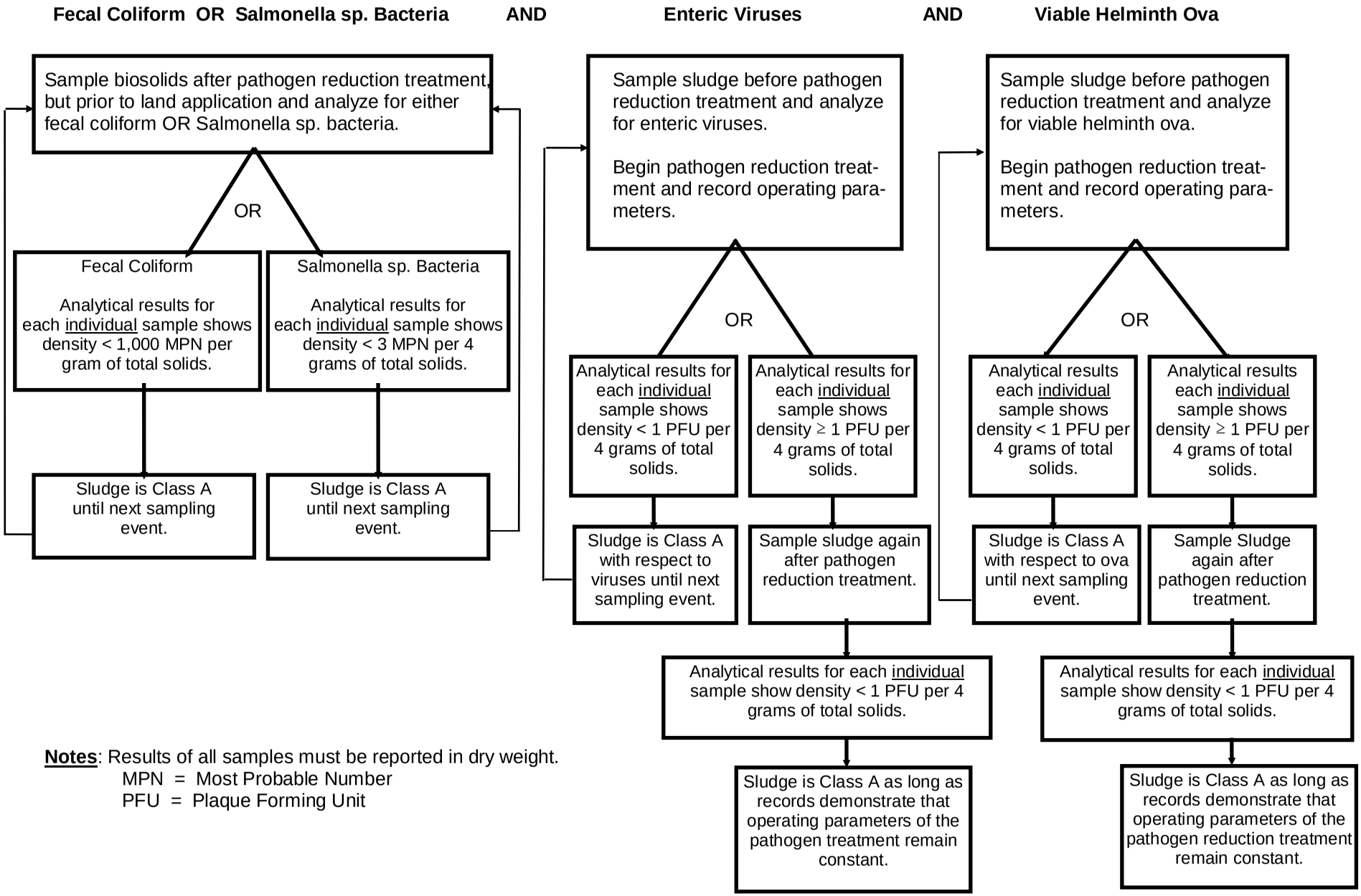
Alternative 4: Treatment by Unknown Processes

Alternative 4 is intended to evaluate the quality of biosolids produced by an unknown process or by a process that is not approved or traditionally recognized as a Class A process. This alternative assesses the biosolids quality at the time the biosolids are beneficially used or at the time the biosolids are prepared for distribution. As with Alternative 3, this alternative relies on direct sampling. Therefore, it is imperative that the microbial sampling program be adequately representative of the final product intended for distribution.

To meet the regulatory requirements under Alternative 4, the biosolids must be analyzed directly for fecal coliforms or Salmonella sp. and helminth ova and enteric viruses at the time the biosolids are processed for distribution or as close as possible to the time the biosolids are beneficially used.

Indicator Organism	Test Result	Outcome
Fecal Coliform or Salmonella sp.	Fecal coliform at time biosolids are used is < 1,000 MPN/gram TS (dry weight) OR Salmonella sp. at time biosolids are used is < 3 MPN/4 grams TS (dry weight)	Class A until next monitoring event as long as the biosolids also meet the enteric virus and helminth ova standards.
AND		
Enteric Virus	Density at the time biosolids are used or prepared for distribution is < 1 PFU/4 grams TS (dry weight)	Class A with respect to enteric virus until next monitoring event.
Helminth ova	Density at the time biosolids are used or prepared for distribution is < 1 viable ova per 4 grams of TS (dry weight)	Class A with respect to Helminth ova until the next monitoring event.

Pathogen Reduction Alternatives 3 & 4 - Analysis & Operation



Notes: Results of all samples must be reported in dry weight.
MPN = Most Probable Number
PFU = Plaque Forming Unit

Alternative 5: Treatment by a Process to Further Reduce Pathogens (PFRP)

Biosolids must be treated by one of the processes listed in §271 Subchapter J Appendix A or as reprinted in this manual in order to be classified as Class A for pathogen reduction. As with all the Class A alternatives, the biosolids must also be monitored and meet the fecal coliform or Salmonella sp. requirements.

Processes to Further Reduce Pathogens (PFRP)

1. **Composting** -- Using either the within-vessel composting method or the static-aerated pile composting method, the temperature of the biosolids are maintained at 131 degrees Fahrenheit (or 55 degrees Celsius) or higher for three days.

   Using the windrow composting method, the temperature of the biosolids is maintained at 131 degrees Fahrenheit (or 55 degrees Celsius) or higher for 15 days or longer. During the period when the compost is maintained at 131 degrees Fahrenheit (or 55 degrees Celsius) or higher, there shall be a minimum of five turnings of the windrow.

2. **Heat Drying** -- Biosolids are dried by direct or indirect contact with hot gases to reduce the moisture content of the sewage sludge to 10 percent or lower. Either the temperature of the sewage sludge particles exceeds 176 degrees Fahrenheit (or 80 degrees Celsius) or the wet bulb temperature of the gas in contact with the sewage sludge as the sewage sludge leaves the dryer exceeds 176 degrees Fahrenheit (or 80 degrees Celsius).

3. **Heat Treatment** -- Liquid biosolids are heated to a temperature of 356 degrees Fahrenheit (or 180 degrees Celsius) or higher for 30 minutes.

4. **Thermophilic Aerobic Digestion** -- Liquid biosolids are agitated with air or oxygen to maintain aerobic conditions and the mean cell residence time of the biosolids are 10 days at 131 to 140 degrees Fahrenheit (or 55 to 60 degrees Celsius).

5. **Beta Ray Irradiation** -- Biosolids are irradiated with Beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (68 degrees Fahrenheit or 20 degrees Celsius).

6. **Gamma Ray Irradiation** -- Biosolids are irradiated with Gamma rays from certain isotopes, such as Cobalt 60 and Cesium 137, at room temperature (68 degrees Fahrenheit or 20 degrees Celsius).

7. **Pasteurization** -- The temperature of the biosolids are maintained at 158 degrees Fahrenheit (or 70 degrees Celsius) or higher for 30 minutes or longer.

Temperature monitoring must be representative of the entire pile or batch of biosolids prepared for beneficial use. In some instances it may be necessary to include areas of the biosolids process, batch or pile that represent a worst case scenario in order to ensure that all the temperatures meet the requirements.

Alternative 6: Treatment by an Equivalent Process to Further Reduce Pathogens

Alternative 6 requires that the biosolids be treated in a process that is equivalent to a PFRP. EPA will determine whether a process is equivalent to a PFRP based on information submitted by the person requesting such a designation.

A request for determination of equivalency should be submitted to the EPA Pathogen Equivalency Committee (PEC), EPA Region 3 biosolids coordinator, DEP Central Office and the appropriate DEP regional biosolids coordinator. Information pertaining to equivalency submittal can be located on the EPA website at www.epa.gov .

Class B Alternatives

Because farms, forests and reclamation lands have a low potential for public exposure and public access can be controlled once the biosolids are applied, biosolids that are applied to these types of sites do not have to meet the strictest pathogen reduction standards. However, when Class B biosolids are applied, site restrictions are required in order to provide an additional level of protection.

Commonly used Class B biosolids treatment processes include anaerobic digestion, aerobic digestion and lime stabilization.

Alternative 1: Monitoring of Indicator Organisms

This alternative uses fecal coliform as an indicator organism. The density of fecal coliform in the treated biosolids product is a predictive measure of the potential presence and density of pathogenic bacteria and viruses. Seven individual grab samples must be collected at the time the biosolids are to be used. The geometric mean of the seven samples must be less than two million colony forming units (CFU) or Most Probable Number (MPN) per gram of total solid on a dry-weight basis in order for the biosolids to be land applied.

The geometric mean of seven samples is used in this alternative to reduce the standard error. A high standard deviation could indicate variability in the sample collection and analysis or that the treatment process is inconsistent with regards to pathogen treatment.

Geometric Mean: The n^{th} root of the product of n numbers. In this case:

Geo. Mean = $\sqrt[7]{S_1 \times S_2 \times S_3 \times S_4 \times S_5 \times S_6 \times S_7}$

Where S_n = fecal coliform density for sample n.

Alternative 2: Processes to Significantly Reduce Pathogens - PSRP

Processes to Significantly Reduce Pathogens (PSRP)

1. **Aerobic Digestion** -- Biosolids are agitated with air or oxygen to maintain aerobic conditions for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between 40 days at 68 degrees Fahrenheit (or 20 degrees Celsius) and 60 days at 59 degrees Fahrenheit (or 15 degrees Celsius).

2. **Air Drying** -- Biosolids are dried on sand beds or on paved or unpaved basins. The biosolids dries for a minimum of three months. During two of the three months, the ambient average daily temperature is above 32 degrees Fahrenheit (or 0 degrees Celsius).

3. **Anaerobic Digestion** -- Biosolids are treated in the absence of air for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature shall be between 15 days at 95 to 131 degrees Fahrenheit (or 35 to 55 degrees Celsius) and 60 days at 68 degrees Fahrenheit (or 20 degrees Celsius).

4. **Composting** -- Using either the within-vessel, static aerated pile or windrow composting methods, the temperature of the biosolids are raised to 104 degrees Fahrenheit (or 40 degrees Celsius) or higher and remains at 104 degrees Fahrenheit (or 40 degrees Celsius) or higher for five days. For four hours during the five days, the temperature in the compost pile exceeds 131 degrees Fahrenheit (or 55 degrees Celsius).

5. **Lime Stabilization** -- Sufficient lime is added to the biosolids to raise the pH of the biosolids to 12 after two hours of contact.

   Using a calibrated pH meter, the pH should be measured at 25^{o}C (77^{o}F) or at the existing temperature and corrected to 25^{o}C when using a temperature compensating meter. Refer to Appendix A of this manual for further information on how to measure pH, calibrate a pH meter and compensate for temperature.

This alternative requires that the biosolids be treated in one of the above PSRPs and that the PSRPs be operated in accordance with the above description at all times. Treatment can occur any time prior to land application of the biosolids.

Alternative 3: Use of Processes Equivalent to PSRP

This alternative requires that the biosolids be treated in a process that is equivalent to a Process to Significantly Reduce Pathogens (PSRP), as determined by the EPA. Equivalency requests are reviewed and determinations made by the PEC. Equivalency applications should also be provided to the EPA Region 3 biosolids coordinator, DEP Central Office and the appropriate regional DEP biosolids coordinator.

Pathogen Reduction - Residential Septage

This pathogen reduction alternative is specific for residential septage and requires the pH of septage to be raised to 12 or higher by alkali addition and held at 12 or higher, without the addition of more alkali, for 30 minutes. In addition, the site restrictions in §271.932 (b) (5) (i) - (iv) must also be met. Each batch of septage must be monitored for pH prior to land application.

Using a calibrated pH meter, the pH should be measured at 25^{o}C (77^{o}F) or at the existing temperature and corrected to 25^{o}C using a temperature compensating meter. Refer to Appendix A of this manual for further information on how to measure pH, calibrate a pH meter and compensate for temperature.

Frequency of Monitoring

How often the biosolids are monitored for the constituents listed above depends on the treatment processes used and the amount of biosolids produced for land application. The following table lists the minimum requirements for sampling frequency. This table can also be found in §271.917(a)(1). The sampling frequency assumes that the biosolids are continuously land applied over a 365-day period.

Amount of Biosolids[1] Tons or (Metric Tons) Per 365-Day Period	**Frequency**
Greater than 0 but less than 319 (290)	Once per year
Equal to or greater than 319 (290) but less than 1,650 (1,500)	Once per quarter (4 / yr)
Equal to or greater than 1,650 (1,500) but less than 16,500 (15,000)	Once per 60 days (6 / yr)
Equal to or greater than 16,500 (15,000)	Once per month (12 / yr)

[1]Either the amount of biosolids land applied or the amount of sewage sludge received by a person who prepares biosolids that are sold, given away or otherwise distributed in a bag or other container for land application.

APPENDIX A

Measuring pH for Biosolids Stabilization

Measurements for pH are required for pathogen reduction Class A Alternative 2, Class B Alternative 2, residential septage and vector attraction Options 6 and 11. The following information summarizes the two accepted methods listed in Appendix C of this manual.

pH Meter Requirements

Both methods require utilization of the potentiometric method, which requires a pH meter with an electrode system.

Accuracy
All meters must be able to measure to the nearest 0.1 pH units.

Calibration
All meters must be able to perform, at a minimum, a two-point calibration.

Calibration
Meters must be calibrated on a daily basis, or each time the unit is used in measuring samples.

Buffers
Use pH buffer solutions of 7 and 10 for two-point calibrations.
Use pH buffer solutions 4,7,10 for three-point calibrations.

Slope
The slope is an important part of the calibration process. It will verify the accuracy of the calibration performed.

Units that display calibration slopes, should have a slope of –57.0 to –62.0, 57.0 to 62, or 95 to 105. Slope ranges depend on the individual meter.

Units that **do not** display calibration slopes should verify the accuracy of the calibration by conducting the following procedure:

- Add 5 grams of powdered lime to 100 to 300 mL of room temperature (25^{o} C or 77^{o} F) tap water.
- Stir to mix solution.
- Take a pH reading. The pH should be between 12.4 and 12.5. If the pH is outside of this range, then the slope is inaccurate and a calibration must be conducted again.

Temperature Correction

Automatic Temperature Compensating Meters
Meters/probes that have an automatic temperature compensation feature allows the user to measure the pH of the sludge at variable temperatures. However, pH readings must be corrected to 25° C. Knowing the temperature of the biosolids sample, use the following formula to correct the pH measurement to 25°C.

pH reading (from meter)	+	pH Correction Factor	=	Adjusted pH

The pH correction factors are located on the last page of this appendix.

For example, biosolids measured at 20°C with a meter reading of 12.15 would be corrected as follows:

12.15	+	- 0.15	=	12.00
pH reading (from meter)	+	pH Correction for 20 °C sample	=	Adjusted pH

Automatic temperature compensating meters are highly recommended for taking pH measurements of biosolids and residential septage.

Non-Temperature Compensating Meters
Buffer solutions must remain at approximately 25° C or 77° F during calibration procedures.

Sludge samples must be measured at approximately 25° C or 77° F.

The target pH for lime and alkali stabilization will always be 12.0.

Buffer Solutions

Powdered Buffer Solutions
If your buffers come in powdered forms, mix with distilled or deionized water (approximately 50 mL).

Shelf life once mixed ≈ two to three days if covered when not in use.

Refer to the expiration date on the powdered buffer solution container and manufacturer's recommended storage procedure.

Premixed Buffer Solutions
If your buffer solution is premixed, pour 50 mL in a small beaker for calibration purposes.

Do not pour back into main container.

Shelf life of 50 mL solution ≈ two to three days if covered when not in use.

Refer to the expiration date on the buffer solution bottle and manufacturer's recommended storage procedure.

General Probe Maintenance

Soak in 0.1 N hydrochloric acid (HCl) for 15 minutes, weekly or as recommended by the manufacturer.

Keep the probe in pH storage solution (potassium chloride, KCl) when not in use.

Keep probe clean of debris.

Approved pH Methods

SM-4500-H^+
This method is used to measure pH for liquid samples. All information mentioned above apply to this method.

Continuously stir sample when taking sample pH readings.

EPA-9045
This method applies to sludge that is in the solid state. All information mentioned above applies to this method.

Samples are measured using the following procedure:

Measure out 20 to 50 grams of sludge and place in small sample beaker. Add as many milliliters of deionized water to as many grams of sludge in the beaker (1:1 water/soil).

Mix vigorously for five minutes. Then allow suspended solids to settle for approximately one minute.

Rest the tip of the probe on top of the suspended solids and obtain the pH reading. Take the pH in several locations. If pH readings are unstable, gently mix the solution and take the reading again.

pH Correction Chart			
Temperature (Celsius)	**pH Correction Factor**	**Temperature (Celsius)**	**pH Correction Factor**
0	-0.75	25	0.00
1	-0.72	26	0.03
2	-0.69	27	0.06
3	-0.66	28	0.09
4	-0.63	29	0.12
5	-0.60	30	0.15
6	-0.57	31	0.18
7	-0.54	32	0.21
8	-0.51	33	0.24
9	-0.48	34	0.27
10	-0.45	35	0.30
11	-0.42	36	0.33
12	-0.39	37	0.36
13	-0.36	38	0.39
14	-0.33	39	0.42
15	-0.30	40	0.45
16	-0.27	41	0.48
17	-0.24	42	0.51
18	-0.21	43	0.54
19	-0.18	44	0.57
20	-0.15	45	0.60
21	-0.12	46	0.63
22	-0.09	47	0.66
23	-0.06	48	0.69
24	-0.03	49	0.72
25	0.00	50	0.75

pH reading (from meter)	+	pH Correction Factor	=	Adjusted pH

APPENDIX B

CONVERSION FACTORS
ENGLISH SYSTEM UNITS TO METRIC SYSTEM UNITS

Name	Abbreviation	Multiplier	Symbol	Name
		Length		
Inch	in	2.54	cm	Centimeter
Foot	ft	0.3048	m	Meter
Mile	mi	1.609	km	Kilometer
		Area		
Square Inch	in^2	6.4516	cm^2	Square Centimeter
Square Foot	ft^2	9.29×10^{-2}	m^2	Square Meter
Square Mile	mi^2	2.59	km^2	Square Kilometer
Square Mile	mi^2	259	ha	Hectare
Acre	acre	0.4047	ha	Hectare
		Volume		
Cubic Foot	ft^3	28.32	L	Liter
Cubic Foot	ft^3	2.832×10^{-2}	m^3	Cubic Meter
Gallon	gal	3.785	L	Liter
Million Gallons	Mgal	3.7854 x 103	m^3	Cubic Meter
Acre Foot	acre-ft	1233	m^3	Cubic Meter
		Pressure		
Pounds per Square Inch	lbs/in^2	7.031×10^{-2}	kg/cm^2	Kilograms per Square Centimeter
		Mass		
Pound	lb	4.539×10^2	g	Gram
Pound	lb	0.4536	kg	Kilogram
Ton (short)	T	0.9072	mt	Metric Tonne
		Density		
Tons per Acre	T/acre	2242.15	kg/ha	Kilogram per Hectare
Tons per Acre	T/acre	2.2421	mt/ha	Metric Tonne per Hectare

CONVERSION FACTORS
ENGLISH SYSTEM UNITS TO METRIC SYSTEM UNITS

Name	Abbreviation	Multiplier	Symbol	Name
		Density (continued)		
Pounds per Cubic Foot	lbs/ft^3	16.02	kg/m^3	Kilogram per Cubic Meter
		Discharge (Flow Rate, Volume/Time)		
Cubic Feet per Second	$ft^{3/}sec$	28.32	L/sec	Liters per Second
Gallons per Minute	gal/min	6.39×10^{-2}	L/sec	Liters per Second
Gallons per Day	gal/day	4.3813×10^{-5}	L/sec	Liters per Second
Million Gallons per Day	Mgal/day	43.8126	L/sec	Liters per Second
Million Gallons per Day	Mgal/day	3.7854×10^3	L/sec	Liters per Second
		Power		
Horsepower	hp	0.7457	kW	Kilowatt
		Temperature		
Degrees Fahrenheit	^oF	$0.555 \times (^oF - 32)$	^oC	Degrees Celsius
		Miscellaneous		
Parts per Million	ppm	1.0	mg/L	Milligrams per Liter
Parts per Billion	ppb	1.0	µg/L	Micrograms per Liter
Million Gallons per Acre	Mgal/acre	9354.537	m^3/ha	Cubic Meters per Hectare

CONVERSION FACTORS
METRIC SYSTEM UNITS TO ENGLISH SYSTEM UNITS

Name	Abbreviation	Multiplier	Symbol	Name
		Length		
Centimeter	cm	0.3937	in	Inch
Meter	m	3.2808	ft	Feet
Kilometer	km	0.6214	mi	Mile
		Area		
Square Centimeter	cm^2	0.155	in^2	Square Inch
Square Meter	m^2	10.763	ft^2	Square Foot
Square Kilometer	km^2	0.3861	mi^2	Square Mile
Hectare	ha	3.861×10^{-3}	mi^2	Square Mile
Hectare	ha	2.471	acre	Acre
		Volume		
Liter	L	3.531×10^{-2}	ft^3	Cubic Foot
Liter	L	0.2642	gal	Gallons
Cubic Meter	m^3	35.3174	ft^3	Cubic Foot
Cubic Meter	m^3	2.641×10^{-4}	Mgal	Million Gallons
Cubic Meter	m^3	8.1071×10^{-4}	acre-ft	Acre-foot
		Pressure		
Kilograms per Square Centimeter	kg/cm^2	14.22	lbs/in^2	Pounds per Square Inch
		Mass		
Gram	g	2.20×10^{-3}	lb	Pound
Kilogram	kg	2.205	lb	Pound
Metric Tonne	mt	1.103	T	Ton (short)
		Density		
Kilogram per Cubic Meter	kg/m^3	0.0624	lbs/ft^3	Pound per Cubic Foot
Kilogram per Hectare	kg/ha	4.46 x 10-4	T/acre	Tons per Acre

CONVERSION FACTORS
METRIC SYSTEM UNITS TO ENGLISH SYSTEM UNITS

Name	Abbreviation	Multiplier	Symbol	Name
		Density		
Metric Tonnes per Hectare	mt/ha	0.446	T/acre	Tons per Acre
		Discharge (Flow Rate, Volume/Time)		
Liter per Second	L/sec	3.531×10^{-2}	ft^3/sec	Cubic Foot per Second
Liter per Second	L/sec	15.85	gal/min	Gallons per Minute
Liter per Second	L/sec	22,824.5	gal/day	Gallons per Day
Liter per Second	L/sec	2.28×10^{-2}	Mgal/day	Million Gallons per Day
Cubic Meters per Day	m3/day	2.6417×10^{-4}	Mgal/day	Million Gallons per Day
		Power		
Kilowatt	kW	1.341	hp	Horsepower
		Temperature		
Degrees Celsius	^oC	$1.8^oC + 32$	^oF	Degrees Fahrenheit
		Miscellaneous		
Milligrams per Liter	mg/L	1.0	ppm	Parts per Million
Micrograms per Liter	µL	1.0	ppb	Parts per Billion
Cubic Meters per Hectare	m^3/ha	1.069×10^{-4}	Mgal/acre	Million Gallons per Acre

APPENDIX C

Analytical References and Methods

1. Enteric Viruses. ASTM Designation: D 4994-89, “Standard Practice for Recovery of Viruses from Wastewater Sludges,” 1992 Annual Book of ASTM Standards: Section 11 - Water and Environmental Technology, ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187.

2. Fecal Coliform. EPA1680, EPA1681 Part 9221 E. or Part 9222 D., “Standard Methods for the Examination of Water and Wastewater,” 18th Edition, 1992, American Public Health Association, 1015 15th Street, N.W., Washington, DC 20005.

3. Helminth Ova. Yanko, W.A., "Occurrence of Pathogens in Distribution and Marketing Municipal Sludges", EPA600/1-87-014, 1987. National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161 (PB 88-154273/AS).

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BIOSOLIDS ANALYTICAL METHODS			
Pollutant	**Analytical Method**	**Maximum Holding Time, Sample Preservation, Sample Container, Sample Preparation**	**Comments**
Arsenic	AA Furnace: SW-846 Method 7060 AA Gaseous Hydride: SW-846 Method 7061 Inductively Coupled Plasma: SW-846 Method 6010	Six Months Plastic or glass container	Samples need to be digested prior to analysis. All samples must be digested using SW-846 Method 3050 or 3051 prior to analysis by any of the procedures indicated. The AA Direct Aspiration analyses are applicable at moderate concentration levels in clean complex matrix systems. AA Furnace methods can increase sensitivity if matrix effects are not severe. Inductively Coupled Plasma (ICP) methods are applicable over a broad linear range and are especially sensitive for refractory elements. Detection limits for ICP methods are generally higher than for AA Furnace methods.
Cadmium	AA Direct Aspiration: SW-846 Method 7130 AA Furnace: SW-846 Method 7131 Inductively Coupled Plasma: SW-846 Method 6010		
Copper	AA Direct Aspiration: SW-846 Method 7210 AA Furnace: SW-846 Method 7211 Inductively Coupled Plasma: SW-846 Method 6010		

BIOSOLIDS ANALYTICAL METHODS			
Pollutant	**Analytical Method**	**Maximum Holding Time, Sample Preservation, Sample Container, Sample Preparation**	**Comments**
Lead	AA Direct Aspiration: SW-846 Method 7420 AA Furnace: SW-846 Method 7421 Inductively Coupled Plasma: SW-846 Method 6010	Six Months Plastic or glass container Samples need to be digested prior to analysis	All samples must be digested using SW-846 Method 3050 or 3051 prior to analysis by any of the procedures indicated. The AA Direct Aspiration analyses are applicable at moderate concentration levels in clean complex matrix systems. AA Furnace methods can increase sensitivity if matrix effects are not severe. Inductively Coupled Plasma (ICP) methods are applicable over a broad linear range and are especially sensitive for refractory elements. Detection limits for ICP methods are generally higher than for AA Furnace methods.
Mercury	Cold Vapor (Manual): SW-846 Method 7470 SW-846 Method 7471	28 days Cool to 4°C Plastic or glass container	▪ SW-846 Method 7470 applies to mercury in liquids. ▪ SW-846 Method 7471 applies to mercury in solid or semisolid wastes. ▪ The digestion procedure is contained in the analytical method.

BIOSOLIDS ANALYTICAL METHODS			
Pollutant	**Analytical Method**	**Maximum Holding Time, Sample Preservation, Sample Container, Sample Preparation**	**Comments**
Molybdenum	AA Direct Aspiration: SW-846 Method 7480 AA Furnace: SW-846 Method 7481 Inductively Coupled Plasma: SW-846 Method 6010	Six Months Plastic or glass container Samples need to be digested prior to analysis	All samples must be digested using SW-846 Method 3050 or 3051 prior to analysis by any of the procedures indicated. The AA Direct Aspiration analyses are applicable at moderate concentration levels in clean complex matrix systems. AA Furnace methods can increase sensitivity if matrix effects are not severe. Inductively Coupled Plasma (ICP) methods are applicable over a broad linear range and are especially sensitive for refractory elements. Detection limits for ICP methods are generally higher than for AA Furnace methods.
Nickel	AA Direct Aspiration: SW-846 Method 7520 Inductively Coupled Plasma: SW-846 Method 6010		
Selenium	AA Furnace: SW-846 Method 7740 or 7051 AA Gaseous Hydride: SW-846 Method 7741 Inductively Coupled Plasma: SW-846 Method 6010		

BIOSOLIDS ANALYTICAL METHODS			
Pollutant	**Analytical Method**	**Maximum Holding Time, Sample Preservation, Sample Container, Sample Preparation**	**Comments**
Zinc	AA Direct Aspiration: SW-846 Method 7520 Inductively Coupled Plasma: SW-846 Method 6010	Six Months Plastic or glass container Samples need to be digested prior to analysis	All samples must be digested using SW-846 Method 3050 or 3051 prior to analysis by any of the procedures indicated. The AA Direct Aspiration analyses are applicable at moderate concentration levels in clean complex matrix systems. AA Furnace methods can increase sensitivity if matrix effects are not severe. Inductively Coupled Plasma (ICP) methods are applicable over a broad linear range and are especially sensitive for refractory elements. Detection limits for ICP methods are generally higher than for AA Furnace methods.
PCBs	SW-846 Method 8082	Amber glass w/Teflon lid	
pH	EPA-9045 SM-4500-H^+	1:1 soil/water	
Total Solids Volatile Solids Fixed Solids	Gravimetric: SW-2540 G	Seven days Cool to 4°C Plastic or glass container	Recommended procedure for solid and semisolid samples.
Total Kjeldahl Nitrogen (TKN)	SM-4500-N_{org} EPA-351.3	28 days Cool to 4°C Plastic or glass container	Total Kjeldahl nitrogen is the sum of organic and ammonia nitrogen in a sample. Sample digestion and distillation are required and are included or referenced in the method.
Ammonia Nitrogen	SM-4500-NH_3	28 days Cool to 4°C Plastic or glass container	All samples must be digested using procedure SM-4500- NH_3 B prior to analysis by one of the specific analysis procedures listed.
Nitrate Nitrogen	SM-4500-NO_3	28 days Cool to 4°C Plastic or glass container	

BIOSOLIDS ANALYTICAL METHODS			
Pollutant	**Analytical Method**	**Maximum Holding Time, Sample Preservation, Sample Container, Sample Preparation**	**Comments**
Plant Available Nitrogen	N-Ammonia: Distillation, Nesslerization SM-4500-NH_3 A,B,C N-Nitrate: Electrode Method SM-4500- NO_3^- A, D	Ammonium and Nitrate Extract with 2N KCl	Inorganic nitrogen is readily available for plant uptake.
Plant Available Nitrogen	SM-4500-P A, B, C, D, E	Extract with 0.03N NH_4F + HCL Extract with dilute HCL + H_2SO_4 Extract with 0.5M $NaHCO_3$ Extract with water	
Fecal Coliform	SM-9221 E (MPN) SM-9222 D (membrane filter) Method 1680	Six hours Cool to 4°C Plastic or glass container (sterile)	Samples must be analyzed within holding times. **Class A alternatives <u>MUST</u> use SM-9221E.**
Salmonella	SM-9260 D.1 Kenner, B.A and H.A. Clark Method 1682	Six hours plastic or glass container	Large sample volumes are needed due to the low concentration of Salmonella in wastewater. Also, due to the large number of Salmonella species, more than one procedure may be necessary to adequately determine the presence of Salmonella.
Enteric Virus	ASTM-Method D 4994-89	Two hours at up to 25°C or 48 hours at 2 to 10°C Plastic or glass container	Concentrations of the sample are necessary due to the presumably low numbers of viruses in the sample.
Helminth ova	Yanko, W.A		See reference list

APPENDIX D

3800-FM-BPNPSM0070 1/2013

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF POINT AND NON-POINT SOURCE MANAGEMENT

WORKSHEET B1
BIOSOLIDS ANNUAL AGRONOMIC LOADING RATE

Field _____ Crop _____

Growing Season Year _____ Yield Goal _____

Site _____

1. Total crop nitrogen requirement
(*From soil analysis, historical data, or Penn State Agronomy Guide*) **1** _____ lb/acre

2. Nitrogen provided from other sources either added to or mineralized in the soil

a. ***Nitrogen contributions from previous years' activities***

1. N from previous legume crop
(Penn State Agronomy Guide) _____ lb/acre
2. Estimate of mineralized organic N from previous biosolids applications
(Supplemental Worksheet Part 2.a.2. from previous 2 years applications)
- This does not apply to previous residential septage applications _____ lb/acre
3. Estimate of available residual N from **historical** manure applications
(*Supplemental Worksheet Part 2.a.3.*) _____ lb/acre

Sum of **(a.1. + a.2. + a.3.)** **2a** _____ lb/acre

b. ***Nitrogen contributions from current year's activities***

1. Estimate of available N from **current** manure application
(*Supplemental Worksheet Part 2.b.1.*) _____ lb/acre
2. N from chemical fertilizers _____ lb/acre
3. N from other sources (ex. food processing waste) _____ lb/acre

Sum of **(b.1. + b.2. + b.3.)** **2b** _____ lb/acre

Total available nitrogen from other sources **(2a + 2b)** **2** _____ lb/acre

3. Adjusted crop nitrogen requirement **(Subtract 2 from 1)** **3** _____ lb/acre

4. Total available nitrogen from biosolids (based on biosolids analysis)

a. NH_4-N

_____ $\%NH_4$ x 2,000 lb/ton = _____ lb/ton NH_4-N

_____ NH_4 lb/ton x _____ K_{vol} (*Vol. Rate Table*) = _____ lb/ton Available NH_4

b. Org-N

_____ %Org-N x 2,000 lb/ton = _____ lb/ton Org-N

_____ Org-N lb/ton x _____ K_{min} (*Min. Rate Table*) = _____ lb/ton Available Org-N

Total plant available nitrogen (PAN) from biosolids **(a + b)** **4** _____ lb/ton Plant Available N

5. Calculate the agronomic loading rate for biosolids application **(Divide 3 by 4)** **5** _____ dry tons/acre

6. Calculate amount of biosolids to be applied **6** _____

☐ **wet tons/acre or** ☐ **gallons/acre**

_____ dry tons/acre ÷ _____ (*decimal*) % solids = _____ **wet tons/acre**

_____ wet tons/acre x 2,000 lb/ton ÷ 8.5 lbs/gallon = _____ **gallons/acre**

7. P_2O_5 and K_2O fertilizer equivalent in biosolids (based on biosolids analysis)
(Nutrient management information for the farmer)

a. _____ % P in biosolids x 2.29 = _____ % P_2O_5 in biosolids

_____ % P_2O_5 x 2,000 lb/ton = _____ lb/ton P_2O_5

b. _____ % K in biosolids x 1.2 = _____ % K_2O in biosolids

_____ % K_2O x 2,000 lb/ton = _____ lb/ton K_2O

APPENDIX E

DEP Regional Offices	
Southeast Region 2 East Main St. Norristown, PA 19401 484-250-5970 Counties: Bucks, Chester, Delaware, Montgomery and Philadelphia	**Northeast Region** 2 Public Square Wilkes-Barre, PA 18711-0790 570-826-2553 Counties: Carbon, Lackawanna, Lehigh, Luzerne, Monroe, Northampton, Pike, Schuylkill, Susquehanna, Wayne and Wyoming
Northcentral Region 208 W. Third St., Suite 101 Williamsport, PA 17701 570-327-3670 Counties: Bradford, Cameron, Clearfield, Centre, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga and Union	**Southcentral Region** 909 Elmerton Ave. Harrisburg, PA 17110-8200 717-705-4707 Counties: Adams, Bedford, Berks, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Mifflin, Perry and York
Southwest Region 400 Waterfront Drive Pittsburgh, PA 15222-4745 412-442-4000 Counties: Allegheny, Armstrong, Beaver, Cambria, Fayette, Greene, Indiana, Somerset, Washington and Westmoreland	**Northwest Region** 230 Chestnut Street Meadville, PA 16335-3481 814-332-6942 Counties: Butler, Clarion, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Venango and Warren

APPENDIX F

References

1. Sludge Handling and Conditioning, EPA 430-9-78-992

2. Control of Pathogens and Vector Attraction in Sewage Sludge, EPA 625-R-92-013

3. Operation of Wastewater Treatment Plants, MOP11, WEF

4. Process Design Manual - Land Application of Sewage Sludge and Domestic Septage, EPA 625-R-95-001

Bureau of Point and Non-Point Source Management
P.O. Box 8774
Harrisburg, PA 17105-8774

For more information, visit www.dep.state.pa.us,
keyword: biosolids.

3800-MN-DEP4081 Rev. 7/2013