W1366

Series Guide for Tennessee Agricultural Producers Applying Biosolids: Class A vs Class B Pathogen Safety Standards

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Shawn Hawkins, Professor, Department of Biosystems Engineering and Soil Science
Forbes Walker, Professor, Department of Biosystems Engineering and Soil Science

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Public Health Considerations

A common question the University of Tennessee Extension receives regarding the land application of treated sewage sludge (referred to herein as "biosolids") is whether it is safe. This concern arises because biosolids are misconstrued as "human waste" which could contain pathogens that cause illness or disease through exposure during or after land application.

Given the misconception, the concern is valid. Disease and illness caused by pathogenic bacteria, viruses and parasites are often spread by human waste contaminating water and soil. The link between municipal sewage and disease was firmly established in the mid-1850s by Dr. John Snow, who documented the distribution of cholera outbreaks in London, England [1]. Dr. Snow recorded far higher incidence of cholera in districts supplied with Thames River drinking water downstream versus upstream of raw sewage discharge points. These findings led to construction of improved "sanitary" sewage collection systems, which for 100 years largely remained conveyances that discharged raw sewage into surface waters. The 1948 Federal Water Pollution Control Act attempted to address this public health concern, but relied on voluntary compliance and was poorly funded and enforced [2]. **For example, the city of Nashville continued to discharge raw sewage into the Cumberland River until 1958.**

The turning point for eliminating this public health threat was the Clean Water Act of 1972 (CWA: 33 USC 1345) which set a national goal to stop "the discharge of pollutants to navigable waters" using a National Pollutant Discharge Elimination System (NPDES). The resulting set of regulations developed by the Environmental Protection Agency (EPA) (40 CFR § 122) strives to achieve this goal by requiring permits to legally discharge pollutants to surface waters. These permits require municipal wastewater treatment plants to (1) remove solids and (2) use biological treatment to lower the wastewater oxygen demand. **These two treatment processes are the source materials for biosolids, a "primarily organic solid product yielded by municipal wastewater treatment processes that can be beneficially recycled" [3].**

Prior to the CWA, treatment standards for the raw sewage sludge derived from primary solids settling (occurring before the biological treatment process) and secondary solids settling (generated by the biological treatment process) were not well established [4]. The CWA directed the EPA to develop treatment standards so that sewage sludge could be safely land applied; The Standards for the Use or Disposal of Sewage Sludge (40 CFR § 503) were published in 1993.

The Standards for the Use or Disposal of Sewage Sludge were developed considering the potential presence of disease pathogens in raw sewage sludge solids (**Table 1**) and nine land application exposure routes (**Table 2**) [5]. The final rules are a mix of testing and highly specific treatment standards that quantify the relative degree of pathogen reduction using a **Class A** or **Class B** designation [3]. These processes reduce the risk of pathogen exposure that occurs during land application of biosolids by: (1) reducing pathogen concentrations and (2) making biosolids less attractive to disease vectors (e.g. flies and rodents) that can transport pathogens from biosolids to humans [5].

Table 1. Principal pathogens of concern in domestic sewage and raw sewage sludge [5]. Pathogen reduction indicator organisms are bold.

Type	Species	Illness/Disease
Bacteria	***Salmonella sp.***	Salmonellosis (food poisoning), Typhoid
	Shigella sp.	Bacillary dysentery
	Yersinia sp.	Acute gastroenteritis
	Vibrio cholerae	Cholera
	Campylobacter jejuni	Gastroenteritis
	Escherichia coli	Gastroenteritis
Viruses	Hepatitis A	Hepatitis
	Norwalk	Epidemic gastroenteritis
	Rotaviruses	Acute gastroenteritis
	Enteroviruses	Poliomyelitis, meningitis, pneumonia, hepatitis, fever, encephalitis
	Reovirus	Respiratory infections, gastroenteritis
	Astroviruses	Epidemic gastroenteritis
	Caliciviruses	Epidemic gastroenteritis
Parasitic Protozoa	*Cryptosporidium*	Gastroenteritis
	Entamoeba histolytica	Acute Enteritis
	Giardia lamblia	Giardiasis
	Balantidium coli	Dysentery
	Toxoplasmodium	Toxoplasmosis
Parasitic Worms	***Ascaris lumbricoides***	Roundworms; nausea, diarrhea, cough
	Ascaris suum	Swine roundworms; fever, cough, chest pain
	Toxocara canis	Dog roundworms; fever, cough, vision loss
	Trichuris trichiura	Whipworms; abdominal pain, diarrhea
	Taenia saginafa	Beef tapeworms; abdominal pain, nausea
	Taenia solium	Swine tapeworms; taeniasis, cysticercosis
	Hymenolepis nala	Dwarf tapeworms; abdominal pain, diarrhea
	Necator americanus	Hookworms; skin rash, cough, anemia

Table 2. Pathogen exposure pathways considering in developing The Standards for the Use or Disposal of Sewage Sludge.

Exposure	Description
Direct	Contact with sewage sludge during loading, unloading, or land application; e.g., when liquid biosolids are applied using splash plates and/or high-pressure hoses/guns or when solid biosolids are applied by using flail or beater type spreaders.
	Walking through fields, pastures, forests, or land reclamation areas where biosolids were recently applied; e.g., exposure due to contaminated footwear that brings pathogens sourced from biosolids to workplaces and homes where direct contact occurs during removal and cleaning.
	Handling soils from a field where biosolids were recently applied; e.g., when collecting crop or soil samples or during installation, relocation, or removal of irrigation equipment that is often used to apply liquid biosolids.
	Inhaling pathogens that become airborne during biosolid land application; e.g., when liquid biosolids are applied using tanker splash plates and high-pressure hoses/guns that generate aerosols or when solid biosolids are applied using flail or beater type spreaders that generate dust.
Indirect	Consumption of pathogen-contaminated crops either grown on fields where biosolids were land-applied or contaminated by field workers; at particular risk are root crops such as potatoes or crops that can contact the soil such as melons and tomatoes.
	Consumption of pathogen-contaminated milk or other animal-sourced food products where the animals have been grazed on fields fertilized with biosolids; it is not uncommon for beef feedlot and dairy livestock to be fed silage crops fertilized with biosolids.
	Drinking surface or well water contaminated with pathogens by rainfall runoff or seepage from fields where biosolids were land-applied; biosolids are most often land-applied in rural areas where domestic groundwater wells are common.
	Consumption of undercooked fish harvested from surface waters contaminated with pathogens by rainfall runoff from fields where biosolids were land-applied.
	Contact with biosolids pathogens transported by vectors from fields where biosolids were land-applied; vectors include flies, rodents, birds, and livestock or pets attracted primarily to free water and any remaining undegraded organic matter in land-applied biosolids.

Biosolids Pathogens Indicators

Untreated sewage sludge can contain a wide variety of pathogenic organisms (**Table 1**) that originate from infected households and from the wastewater discharged from medical facilities and abattoirs. It is impractical to test sewage sludge for every pathogen that might be present; **The Standards for the Use or Disposal of Sewage Sludge adopted sampling and testing requirements using indicator organisms.** The results provide information about the effectiveness of sewage sludge treatment processes designed to reduce or eliminate pathogens that are often concentrated from wastewater into raw sewage sludge [6]. The indicator concentrations are critically important to evaluate biosolids safety because some types of pathogenic bacteria multiply under favorable conditions in raw sewage sludge (enteric viruses and parasites, on the other hand, can only multiply inside a human or animal host) [6].

The indicator pathogen used to evaluate the relative concentration of biosolids bacterial pathogens is Salmonella; strains of these bacteria are near universally present in municipal wastewater [5, 6]. Salmonella are typically present at higher numbers than other types of pathogenic bacteria in wastewater and share or exceed the hardiness of other bacterial pathogens to treatment processes designed to eliminate them. In short, if Salmonella cannot be cultured from biosolids, it is assumed that other less abundant and less resilient bacterial pathogens are also absent [5]. The detection limit for the Salmonella is 3 per 4 dry grams of sewage sludge solids (0.15 ounces) measured using a most probably number (MPN) culture assay.

For enteric (intestinal) viral pathogens, which tend to be much less hardy that pathogenic bacteria [5, 7], a growth assay is available that enumerates several types of Enteroviruses (**Table 1**). If the viral counts from this assay indicate these viruses are absent from treated sewage sludge, other types of enteric viruses are also assumed to be eliminated [5]. The detection limit is 1 plaque forming unit (PFU) per 4 dry grams of sewage sludge solids.

Intestinal worm (helminth) eggs are often present in municipal wastewater (**Table 1**). Ascaris worms infect a quarter of the world's population, mostly in developing countries and hook worms not uncommon in developed countries [5, 6]. These parasites replicate within a host and release eggs to the intestinal tract; these eggs are very durable and can survive for long periods of time in soil. Ascaris eggs have the highest survivability of the helminths found in raw sewage sludge and are more resistant to treatment inactivation than parasitic protozoa (**Table 1**). Therefore, if treatment conditions remove viable Ascaris eggs from sewage sludge, all other helminth species, as well as parasitic protozoa, are assumed to eliminated [5]. The detection limit is 1 viable egg per 4 dry grams of sewage sludge solids.

A global but generally non-pathogenic indicator of the effectiveness of sewage sludge treatment is the fecal coliform bacteria concentration. These intestinal bacteria are present at very high numbers in raw sewage sludge (≈1-100 million per dry gram of solids) [5]. Thus, the fecal coliform assay provides a broad indication of pathogen deactivation during sewage sludge treatment [5]. The detection limit is 1,000 MPN per dry gram of sewage sludge solids.

Class A and Class B Pathogen Reduction Standards

For treated sewage sludge to be land applied, it must qualify as either Class A (the goal is to eliminate pathogens below detection limits) or Class B (the goal is to significantly reduce pathogen concentrations so that land application is safe using site restrictions). There are six alternatives available to meet the rigorous Class A designation (**Table 3**); three treatment alternatives are available for meeting the less stringent Class B designation (**Table 4**). In addition to meeting a pathogen reduction treatment standard, one of the related set of treatments options must be implemented to reduce the attractiveness of the biosolids to vectors (**Table 6**).

Class A. The Class A designation, which indicates the biosolids do not contain detectable pathogens of any type, is required if the biosolids are:

- sold or given away in a bag or container.
- applied in bulk to lawns or gardens.
- applied in bulk to agricultural fields where site restrictions are not feasible.

To qualify as a Class A biosolids, one of the pathogen reduction standards in **Table 3** must be met before or during implementation of a vector attraction reduction standards in **Table 6**. This timing requirement prevents the growth of pathogens the biosolids become contaminated after the Class A pathogen reduction treatment is complete. Regrowth is prevented by drying, raising the pH, removing degradable organic matter, and/or using high concentrations of competitive non-pathogenic bacteria [5]. In practice, only options 1-8 in **Table 6** are used to meet the Class A standard because of the pathogen testing and timing requirements discussed below [7].

A final Class A criterion requires samples of biosolids to be collected and analyzed for the concentration of fecal coliform or Salmonella pathogen indicators; the results must be below the assay detection limit. These samples must be taken at the time the biosolids are available for disposal. If **Table 3** Alternatives 3 and 4 are used to meet the Class A qualification, the samples must also be the below detection limit for enteric viruses and viable *Ascaris* sp. eggs.

Class B. The pathogen reduction standards in **Table 5** and vector attraction reduction standards **Table 6** qualify biosolids as Class B. The Class B standard only applies to bulk biosolids land applied with strict adherence to the site restrictions in **Table 6**. The site restrictions make the process of land applying Class B biosolids safe using a benchmark of 1 infection per 10,000 individuals exposed per year [3]. The site restrictions (1) eliminate pathogens using exposure to sunlight, drying and microbial competition at land application sites, (2) protect the public by limiting access to land application sites and (3) protect the public by implementing harvest restrictions that consider whether the crop product can contact biosolids amended soil:

- Row Crops, Not Touching Soil
  - Corn, wheat, oats, barley, cotton, soybeans
- Fruit, Not Touching Soil
  - Peaches, apples, oranges, grapefruit
- Vegetables, Touching Soil
  - Melons, strawberries, squash, tomatoes, cucumbers, lettuce
- Root Crops
  - Potatoes, peanuts, onions, leeks, radishes, turnips, beets

Table 3. Class A pathogen treatment requirements.

Alternative	Technical Requirements		
1. Thermal Treatment Based on a formula-based relationship between time in Days (D) at Temp (t)	**Regime A**: Biosolids ≥ 7% solids	Min Temp ≥ 50 C (≥ 122 F) Min Time ≥ 20 minutes	
	Regime B: Small particle biosolids ≥ 7% heated with hot gases or immiscible fluids	Min Temp ≥ 50 C (≥ 122 F) Min Time ≥ 20 minutes	$D = \frac{131{,}700{,}000}{10^{0.14t}}$
	Regime C: Biosolids < 7% solids	Min Time 15s Max Time 30 minutes	
	Regime D: Biosolids < 7% solids	Temp ≥ 50 C (≥ 122 F) Time ≥ 20 minutes	$D = \frac{50{,}070{,}000}{10^{0.14t}}$
2. High pH/Temperature An alkaline material (typically lime) is added to the sewage sludge	Increasing pH	Raise pH ≥ 12 Time ≥ 72 hours	
	Increasing pH and temperature	Raise pH ≥ 12 & Temp ≥ 52 C Time ≥ 12 hours	
	Air Drying	Air dry to 50% solids after 72 hours at elevated pH	
3. Other Processes	Know treatment processes that do not raise the pH or temperature of sewage sludge	Biosolids samples contain no enteric viruses or viable helminth eggs (<1 per 4 grams of dry solids)	
4. Unknown Processes	Unknown or less stringent treatment processes	Each batch of biosolids contain no enteric viruses or viable helminth eggs (<1 per 4 grams of dry solids)	
5. Employ a Process to Further Reduce Pathogens (PFRP)	**Composting.** Static pile: ≥ 55 C (131 F) for ≥ 3 days. Windrowing: 55 C (131 F) for 15 days, 5 turns. **Heat Drying.** Drying with hot gases to > 10% solids with biosolids reaching 80 C (176 F). **Heat Treatment.** Liquid biosolids (<2% solids) heated to ≥ 180 C (356 F) for 30 minutes. **Thermophilic Aerobic Digestion.** Liquid biosolids (<2% solids) are aerated for 10 days at 55 C (131 F). **Beta Ray Irradiation.** Biosolids are irradiated with beta rays ≥ 1 megarad at 20 C (68 F). **Gamma Ray Irradiation.** Biosolids are irradiated with gamma rays at 20 C (68 F). **Pasteurization.** Biosolids are heated ≥ 70 C (158 F) for ≥ 30 minutes.		
6. Process Equivalent to a PFRP above	Rarely used. Requires a site specific or national permit authority approved equivalency test to show that site specific treatment process consistently reduces pathogen levels to levels equivalent to Option 5 above for enteric viruses and viable helmet eggs.		

Table 4. Class B pathogen treatment requirements.

Alternative	Technical Requirements
1. Monitor Fecal Coliform Bacteria	Seven samples of the biosolids must be taken over a two-week period when they are ready to be land applied. The geometric mean of the fecal coliform concentration must be ≤ 2 million per gram dry solids.
2. Employ a Process to Significantly Reduce Pathogens (PSRP)	**Aerobic Digestion.** Sewage sludge is placed in an aerobic reactor where it is aerated (e.g. by blowers and diffusers), typically maintaining the oxygen concentration at a minimum of 1-2 mg/L. The average time the sewage sludge remains in the reactor must be between: - 40 days at 20 C (68 F) - 60 days at 15 C (59 F) **Air Drying.** Sewage sludge must be placed in a drying basin, typically on a sand bed, with the following op-erational specifications: - 3-month total minimum drying time - 1-month minimum drying time at an average daily temperature ≥ 0 C (32 F) **Anaerobic Digestion.** Sewage sludge is placed in anerobic reactor where oxygen is absent. The average time the sewage sludge remains in the reactor must be: - 15 days at 35 to 55 C (68 to xx F) - 60 days at 20 C (68 F) **Composting.** Using a standard composting method (within-vessel, static aerated pile, windrows) the temperature must be: - ≥ 40 C (104 F) for 5 days - ≥ 55 C (131 F) for 4 hours **Lime Stabilization.** An alkaline additive, typically quicklime, hydrated lime, lime kiln dust, cement kiln dust, or fly ash, is added to a reactor containing sewage sludge so that: - pH ≥ 12 for ≥ 2 hours
3. Process Equivalent to PSRP above	Air Drying Air dry to 50% solids after 72 hours at elevated pH

Table 5. Biosolids vector attraction reduction treatment options; one must be completed prior to land application.

Option	Applicable Treatment Method & Technical Requirements
1	**Provide a 38% reduction in volatile solids content using aerobic or anaerobic digestion of sewage sludge.** The digestate can be additionally processed in drying beds, lagoons, or by composting.
2	**Anaerobically digested sewage sludge that cannot meet Option 1.** A 40-day anerobic bench scale test at 30-37 C (86-99 F) results in ≤ 17% reduction in volatile solids content.
3	**Aerobically digested liquid (< 2% solids) sewage sludge that cannot meet Option 1.** A 30-day aerobic bench scale test at 20 C (68 F) results in ≤ 15% reduction in volatile solids content.
4	**Aerobically digested liquid (< 2% solids) sewage sludge that cannot meet Option 1.** Demonstrate the digestate specific oxygen uptake rate is ≤ 1.5 mg of oxygen per dry gram of biosolids at 20 C (68 F).
5	**Composting with an organic bulking agent.** Aerobic treatment for ≥ 14 days during which time the temperature must remain ≥ 40 C (104 F) and the average temperature exceeds 45 C (114 F).
6	**Alkali (typically lime) treatment.** Raise the pH to 12 for at least 2 hours; alternatively raise the pH to 11.5 for 22 hours (must occur without the addition of extra lime during specified time periods).
7	**Moisture reduction of biosolids that do not contain un-stabilized sewage sludge.** Dry to a solids con-tent ≥ 75%; these solids cannot contain settled sewage solids generated prior to biological treatment.
8	**Moisture reduction of biosolids containing un-stabilized solids.** Dry to a solids content ≥ 90%; these solids must be protected from re-wetting or adsorbing moisture.
9	**Soil Injection.** Biosolids must be injected within 8 hours of pathogen treatment below the soil surface with no significant amount of biosolids present on the soil surface within 1 hour of injection.
10	**Soil Incorporation.** Biosolids must be incorporated into soil within 6 hours of placement on the soil sur-face; placement on the soil surface must occur within 8 hours of pathogen treatment.

Table 6. Site restrictions for the land application of Class B biosolids.

Restrictions Targeting		Quarantine and Restriction Specifications
Grazing Animals		30-day period grazing prohibition after biosolids application; generally, it applies to pasture forages
Public Contact		1-year restricted access when biosolids are applied to public lands; restriction can occur with fencing and no trespassing signs
		30-day restriction on public access to privately owned agricultural fields; Limited access can be realized
Harvest	**Food, feed, and fiber crops that do not touch the surface of the soil**	30-day harvest restriction period after biosolids are applied
	Food crops with edible above ground parts that can touch the soil	14-month harvest restriction period after biosolids are applied
	Food crops with edible parts below the soil surface	20-month harvest restriction period after biosolids are surface applied and are not incorporated for more than 4 months
		38-month harvest restriction period after biosolids are surface applied and are incorporated for more than 4 months
	Turf	12-month harvest restriction after the application of biosolids when the turf is placed on land with a high potential for public exposure or on a residential lawn

Class A vs. Class B Biosolids Land Application in Tennessee

In 2018, 110,000 dry metric tons (≈ 121,000 tons) of treated sewage sludge were generated in Tennessee, most of which (63 percent) was land applied (**Figure 1**). Most of the land application was to agricultural lands as a Class B product (53 percent). Only 10 percent of the biosolids were applied as Class A, all of which also qualified as an Exceptional Quality (EQ) product making land application exempt from permitting. Most of the Class A EQ biosolids were generated by Nashville Metro at their Central Wastewater Treatment Plant and land applied on farms in Robertson County. Class A/EQ biosolids are available in Athens, Cookeville, Crossville, Dickson, Franklin, Gallatin, Lebanon, Maryville, Pigeon Forge, Athens, Newport, McMinnville and Newport.

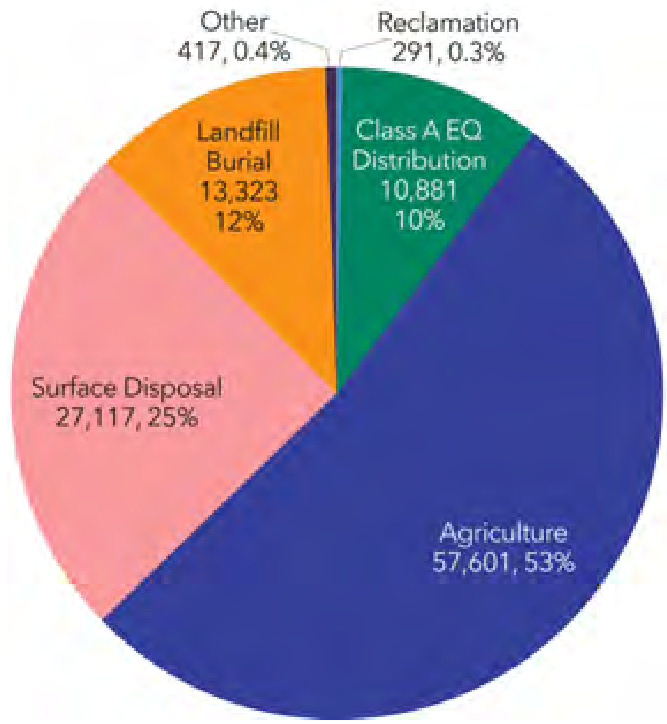

Figure 1. *Tennessee biosolids use and disposal practices in 2018 (biosolidsdata.org/tennessee).*

Agricultural producers should anticipate that biosolids that are available for land application will be a Class B product. The Tennessee Department of Environment and Conservation Division of Water Resources (TDEC-DWR) issues a Tennessee Biosolids State Operating Permit to any utility that land applies Class B biosolids (TDEC-DWR publication CN-1393). These permits are maintained in an online database with public access in the TDEC-DWR Data Viewer; the permit requires that every land application field that receives biosolids is included in a Land Application Plan. The utility that generates the Class B biosolids, or a contracted professional biosolids and/or residuals management company such as Synagro or Denali Water Solutions, will manage and perform the land application on a cooperating agricultural producer's fields at a nitrogen based agronomic rate. Producers should ask for a nutrient/lime equivalency analysis of the biosolids product; tests to establish the biosolids nutrient concentrations are required. Class B biosolids are often applied at no expense to the producer, however **producers can expect to be contractually obligated to the site restrictions in Table 6.**

Some agricultural producers may have access to bulk Class A biosolids; all or virtually all Class A biosolids in Tennessee also qualify as EQ biosolids and do not require a Tennessee Biosolids State Operating Permit. Class A-EQ biosolids do not carry site restrictions. Producers should expect to purchase these biosolids and should again ask for a nutrient/lime equivalency analysis to establish value. In most cases, the land application process will still be managed by a residuals management company; the land application rate (tons/ac) can be negotiable.

Conclusions

A common question the University of Tennessee Extension receives is whether it is safe to land apply biosolids or "human waste." **Biosolids are not "human waste"; biosolids are treated sewage sludge solids** that originate from the solids settling and biological treatment processes required at municipal wastewater treatment plants. The treatment processes are designed to reduce the concentration of a broad spectrum of potential pathogens present in municipal wastewater and concentrated in raw sewage sludge (**Table 1**). These treatment processes are designed to eliminate pathogen exposure risk during land application (**Table 2**). This publication describes The Standards for the Use or Disposal of Sewage Sludge, a set or regulatory rules which designate biosolids as either Class A and Class B, quantifying the relative effectiveness of pathogen reduction. **Biosolids cannot be land applied without first qualifying as either Class A or Class B.**

Class A biosolids meet rigorous pathogen reduction sewage sludge treatment standards (**Table 3**) either before or during implementation of alternatives 1-8 of the vector attraction reduction treatment standards in **Table 5. After meeting these treatment standards, the biosolids are tested to confirm they do not contain detectable pathogen indicators.** For this reason, site restrictions are not required for Class A biosolids, but they are not widely available (**Figure 1**).

Class B biosolids represent the vast majority of the biosolids that are land applied in Tennessee (**Figure 1**). These biosolids must meet the stringent pathogen reduction treatment standards in **Table 4** and one of the vector attraction reduction standards in **Table 5.** The number of pathogens are greatly reduced in Class B biosolids, but they are not eliminated. For this reason, Class B biosolids carry land application site restrictions (**Table 6**). **Class B biosolids must be land applied using a TDEC approved Land Application Plan covered by a Tennessee Biosolids State Operating Permit.** Class B biosolids are not typically land applied by agricultural producers; expect a utility or utility contractor to land apply biosolids on your fields and to be contractually obligated to the site restriction in **Table 6**. A critical proactive step for producers to take with Class A or B biosolids is to ask for a nutrient/lime equivalency analysis.

In short, agricultural producers can be assured that the Class A and Class B designations indicate biosolids are safe to land apply because they have been treated to rigorous standards designed to eliminate the transmission of pathogens. Biosolids can provide free or inexpensive crop nutrients (N, P and a host of micronutrients) as well as much needed soil organic matter. In cases where the biosolids have been lime stabilized, biosolids can also be used as a liming material.

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Online Resources

Clean Water Act of 1972 (CWA: 33 USC 1345): law.cornell.edu/uscode/text/33/1345

National Pollutant Discharge Elimination System (40 CFR § 122): ecfr.gov/current/title-40/chapter-I/subchapter-D/part-122

The Standards for the Use or Disposal of Sewage Sludge (40 CFR § 503): ecfr.gov/current/title-40/chapter-I/subchapter-O/part-503

Tennessee Biosolids State Operating Permit (TDEC-DWR publication CN-1393): tn.gov/environment/permit-permits/water-permits1/biosolids-state-operating-permit.html

Tennessee Department of Environment and Conservation – Division of Water Resources Data Viewer: dataviewers.tdec.tn.gov/dataviewers/f?p=2005:34001:13177164067383:::RR,34001:IREQ_PERMIT_TYPE:Biosolids

National Biosolids Data Project: biosolidsdata.org/tennessee

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