University Curriculum Development for Decentralized Wastewater Treatment

Septage - Biosolids

Text

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Septage - Biosolids

Introduction

The 275 million humans that live in the United States also produce an environmentally significant amount of waste. Septage - Biosolids are the nutrient-rich organic materials generated during the treatment of human sewage waste. The federal government has strict safety standards for biosolids. The federal biosolids rule is contained in 40 CFR Part 503 and is a major focus of the Resource Conservation and Recovery Act (RCRA). It contains the regulations and quality standards for biosolids land application. It clearly divides Biosolids into a number of categories one of theme septage. Septage is the waste coming from septic tanks, Aerobic treatment units and portable toilets. Just like biosolids septage has a number of specific regulations in the 503 regulations. The rule places numerical limits for metals and pathogens for site restrictions, crop harvesting and monitoring, record keeping, and reporting. The newest additions include limiting concentrations on dioxin and dioxin like compounds to ensure safe land application. Only biosolids that meet the most stringent standards spelled out in the Federal and state regulations can be approved for use as a fertilizer. The National Academy of Sciences has concluded "the use of these materials in the production of crops for human consumption when practiced in accordance with existing federal guidelines and regulations, present negligible risk to the consumer, to crop production, and to the environment." Currently, biosolids are used on less than one percent of the nation's agricultural land.

The number and type of requirements associated with the land application of septage are affected not only by quality (pollutant levels, level of pathogen reduction, and attractiveness to vectors), but also by the method of distribution. Biosolids that meet the most stringent limits for all three of the quality parameters are referred to as Exceptional Quality (EQ) sewage. Sludge that does not meet the limits for any or all three parameters is referred to as non-EQ sewage sludge. Biosolids are also classified by pathogen concentration. Class A biosolids are sewage sludge that has undergone treatment by processes that result in a product that is virtually pathogen-free. Class B biosolids have undergone treatment that significantly reduces pathogen concentration but does not completely eliminate it[4]. Measurement of the pollutant concentration is done in three different ways. Pollutant concentration limit (PC) is the maximum concentration for biosolids whose trace element pollutant additions do not require tracking. Cumulative pollutant loading rate (CPLR) is the total amount of pollutant that can be applied to a site in its lifetime by all bulk biosolids applications. The annual pollutant-loading rate (APLR) is the total amount of pollutant that can be applied in a year[5]. The regulations and land applications of biosolids are summarized in Table 1 and 2.

Table 1. Summary of Regulatory Requirements for Different Types of Biosolids

Type of Biosolids and Class of Pathogens	Meet Ceiling Conc. Limits	Meet Pollutant Conc. Limits	Site Restrictions	General Req. and Management Practices	Track Added Pollutants
EQ					

Bag or Bulk Class A	Yes	Yes	No	No	No
PC Bulk Only Class A	Yes	Yes	No	Yes	No
PC Bulk Only Class B	Yes	Yes	Yes	Yes	No
CPLR Bulk Only Class A	Yes	No	No	Yes	Yes
CPLR Bulk Only Class B	Yes	No	Yes	Yes	Yes
APLR Bag Only Class A	Yes	No	No	Yes	Yes

EPA Guide to Part 503 Rule

Table 2. Applications for Biosolids Beneficial Use

Biosolids Option	Pathogen Class	Type of Land	Other Restrictions
EQ	A	All	None
PC	A	All except lawn and home gardens	Management Practices
	B	All except lawn and home gardens	Management Practices and Site Restrictions
CPLR	A	All except lawn and home gardens	Management Practices
	B	All except lawn and home gardens	Management Practices and Site Restrictions
APLR	A	All, but most likely lawns and home Gardens	Labeling Management Practice

Domestic septage is the residue pumped from an onsite wastewater treatment tank, including waste from septic tanks, holding tanks, aerobic tanks, and pump tanks. The second broad category that falls into domestic septage is portable toilets. All the wastes that come from these are included as domestic septage.

Table 3. Characteristics of Septage: Conventional Parameters

	Concentration (mg/L)		
Parameter	**Average**	**Minimum**	**Maximum**
Total solids	34106	1132	130475
Total volatile solids	23100	353	71402
Total suspended solids	12862	310	93378
Volatile suspended solids	9027	95	51500
Biochemical oxygen demand	6480	440	78600
Chemical oxygen demand	31900	1500	703000
Total Kjeldahl nitrogen	588	66	1060
Ammonia nitrogen	97	3	116
Total phosphorus	210	20	760
Alkalinity	970	522	4190
Grease	5600	208	23368
pH	-	1.5	12.6

EPA (1994)

Table 4. Characteristics of Septage: Metals and Organics

	Concentration (mg/L)		
Parameter	**Average**	**Minimum**	**Maximum**
Metals			
Iron	39.3	0.2	2740
Zinc	9.97	<.001	444
Manganese	6.09	0.55	17.1
Barium	5.76	0.002	202
Copper	4.84	0.01	261
Lead	1.21	<0.025	118
Nickel	0.526	0.01	37
Chromium (total)	0.49	0.01	34
Cyanide	0.469	0.001	1.53
Cobalt	0.406	<0.003	3.45
Arsenic	0.141	0	3.5
Silver	0.099	<0.003	5
Cadmium	0.097	0.005	8.1
Tin	0.076	<0.015	1
Mercury	0.005	0.0001	0.742
Organics			

Methyl alcohol	15.8	1	396
Isopropyl alcohol	14.1	1	391
Acetone	10.6	0	210
Methyl ethyl ketone	3.65	1	240
Toluene	0.17	0.005	1.95
Methylene chloride	0.101	0.05	2.2
Ethylbensene	0.067	0.005	1.7
Benzene	0.062	0.005	3.1
Xylene	0.051	0.005	0.72

EPA (1994)

Septage is generally disposed at a wastewater treatment plant, stored and treated separately, treated at a septage facility or land applied. Septage disposal can cause problems for wastewater treatment plants by overloading the system.

Figure C-17: Characteristics of Septage in Minnesota

characteristic	mean values Brainerd area	 White Bear Lake
chemical oxygen demand*	16,100 mg/l	13,600 mg/l
total solids	1.9	4.3%
volatile solids	1.0%	2.4%
total Kjeldahl nitrogen	486 mg/l (4.05lbs/1,000gal)	983 mg/l (8.2lbs/1,000gal)
nitrogen as nitrate	115 mg/l (0.96lbs/1,000gal)	133 mg/l (1.11lbs/1,000gal)

*Chemical oxygen demand (COD) is a measure of the amount of oxygen necessary to decompose all organic matter. COD is usually higher than BOD because more compounds can be oxidized chemically than biologically.

Large loads of BOD can shock a wastewater treatment plant and impair treatment. Most plants can change how the septage is added in order to lessen the impact; and you may receive instruction as to where the septage should be delivered. It's key to get approval from the plant. The septage can also be treated separately. Typically this is reducing the water content and shipping the septage. In a number of areas the composting of septage has also been considered. The ability to compost in usually related to the market for compost and the local regulations.

The basics to discharge septage to WWTP without negative impacts include a number of basic elements.

1) A staging area (with a large holding tank) @ the WWTP so that the septage is slowly metered into the WWTP, and

2) Application of septage at a designated entry point that is physically removed from the WWTP (such as a sewer manhole) so that the septage is slowly added to the sewage at the WWTP proper (only do this with the approval of the WWTP). Some of our city treatment plants have built appropriate facilities to do this and to protect their treatment process from the negative impacts of dumping large amounts of septage into the WWTP all at one time.

Land application can use the beneficial components of the septage and treat the contaminants of concern contained in the septage. Septage land application is also regulated with the federal 503 requirements. The three main requirements in the 503 regulations is 1) Treatment of the septage before placement, 2) Proper placement of the septage, and 3) Record keeping.

Table 5. Summary of Septage Stabilization Options

Method	**Description**	**Advantages**	**Disadvantages**
Alkali stabilization	Lime or other alkaline material is added to liquid septage to raise pH to 12.0 for a minimum of 30 min.	• Very simple; minimal operator attention. • Low capital and O&M costs. • Provides temporary reduction in sulfide odors. • Meets EPA criteria for reduction in vector attraction. • Reduces EPA site restriction requirements for land application.	• Increases mass of solids requiring disposal. • Handling of lime may cause dust problems. • Lime feed and mixing equipment require regular maintenance.
Aerobic digestion	Septage is aerated for 15d to 20d in an open tank to achieve biological reduction in organic solids and odor potential. (Time requirements increase with lower temperatures.)	• Relatively simple. • Can provide reduction in odors.	• High power cost to operate aeration system. • Large tanks or basins required. • Cold temperatures require much longer digestion periods.
Anaerobic digestion	Septage is retained for 15d to 30d in an enclosed vessel to achieve biological reduction in organic solids.	• Generates methane gas, which can be used for digester heating or other purposes.	• Requires skilled operator to maintain process control. • High maintenance requirements for gas handling equipment. • High capital costs. • Generally not used except for co-treatment with sewage sludge.
Composting	Liquid septage or septage solids are mixed with bulking agent (e.g., wood chips, sawdust) and aerated mechanically or by turning. Biological activity generates temperatures sufficiently high to destroy pathogens.	• Final Product is potentially marketable and attractive to users as soil amendment.	• Costly materials handling requirement. • Requires skilled operator process control. • High odor potential. • High operating costs.

EPA (1994)

Septage Treatment with Lime

The purpose of adding lime to septage is to remove pathogens. The high pH kills the bacteria. Lime also breaks down bacteria, allowing the septage to settle better. So you get a higher retention of solids by adding lime to septage.

The other purpose of lime is to avoid attracting vectors. Dead bacteria don't produce odor as live bacteria do, so that vectors are not alerted to the presence of the septage.

Lime does not change the septage's nutrient content. It may even allow nutrients to reach surface water more quickly, so it's critical to consider the slope of the land to which you're applying septage.

Lime must be added properly. The goal is to achieve a pH of 12 for 30 minutes, an alkalinity and time period that will kill pathogens. The rate of lime to septage is approximately 25 pounds of lime per 1,000 gallons of septage.

There are a number of ways to add the lime. One is to draw powdered lime as a solid into your tank. Be careful to avoid bringing it into the pumps since lime dust can cause damage to your equipment. The other way to do it is to add the lime as a slurry: first mix the lime with water, and then add it. The important thing is to get a good mix in your tank as you add the lime. Avoid safety problems when working with lime. Protection of the eyes and lungs is very important, so wear goggles and a dust mask.

CAUTION: Quicklime is more reactive than hydrated lime and it releases a lot of heat. If quicklime is used, you must take safety precautions! Quicklime can cause ban burns if it gets onto moist skin or into your eyes. Appropriate safety precautions include the use of rubberized gloves, a respirator to exclude dust, protective eyewear and clothing to keep moist skin from contacting the quicklime. In addition, a fire could start if a bag of quicklime gets wet and sits around. Any fire involving quicklime must be put out using a chemical extinguisher.

Table 6. Procedure for Lime-Stabilizing Septage within the Pumper Truck

Purpose	To raise the pH of septage to 12 for a minimum of 30 min.
Approach	• Add lime slurry in sufficient quantity *before* pumping the tanks and add additional slurry as needed *after* pumping. • Add lime slurry in sufficient quantity during pumping the tanks by vacuuming slurry through small suction line fitted to main suction hose.
Type of lime	• Pulverized quicklime (CaO). • Hydrated lime ($Ca(OH)_2$). (Less quicklime is required than hydrated lime to achieve the same pH, but quicklime is more corrosive and difficult to handle.)
Dosage	Typically 20 to 25 lb quicklime per 1,000 gal of septage (or about 26 to 33 lb of hydrated lime per 1,000 gal).
Slurry	Approximately 80 lb of pulverized quicklime or hydrated lime in 50 gal of water. Mix manually with paddle in a 55-gal drum or in a 200-gal polyethylene tank with electric mixer (preferred). CAUTION: Heat is liberated when quicklime is added to water. Wear rubber gloves, appropriate respirator (for dust), and goggles. Add lime slowly to partially full tank. An emergency eyewash station should be located nearby.

Application rate	Typically 12 to 15 gal quicklime slurry per 1,000 gal of septage (or 15 to 20 gal hydrated lime slurry).
Monitoring	After lime slurry has been mixed with septage, collect sample from top access hatch using a polyethylene container fastened to a pole. Measure pH with pH meter. (pH paper can also be used, but it is more cumbersome and less accurate.) If the pH is less than 12, add more slurry. If pH 12 has been reached, record pH and time. Sample again after 15 min. If the pH has dropped below 12, add more lime. *The pH must remain at 12 for at least 30 min.* Sample and record pH prior to applying septage to the land.

EPA (1994)

Land Application Area Design Considerations

The practicality of septage land application is based in chemistry. Septage contains many nutrients that are essential for crop growth and yield. These nutrients are typically met using chemical fertilizers. Human waste contains nitrogen, phosphorous, potassium, and trace elements like calcium, copper, iron, magnesium, manganese, sulfur, and zinc. For land application of these wastes, this chapter will mainly focus on nitrogen, potassium, and phosphorous. The amount of nutrient availability varies depending on the type of waste, the season, and the type of application.

Before applying septage to a field, there are specific pieces of information needed to find that will affect the application. These may include soil testing, waste sampling, crop requirements, and nitrogen losses. All are important steps in the application process. If one under-applies the nutrients, the yield and profit suffers. This will minimize the ability to apply in the future. Over-application can lead to excess costs and increased pollution potential. Getting the right amount of septage applied is critical.

Storage

The use of storage at the site can be helpful. Quicker unloading, time to allow for the reaction with lime and dealing with poor weather conditions are some of the main reasons. The size of the storage will be dependent on the reason for the use. Typically bad weather is the single largest need and would set the largest detention time. It also prevents it from being purely a disposal function. For nutrient application to have agronomic viability, then storage is critical in the short term. Here is why. Without storage and mixing of different loads, then the land application site basically becomes similar to a patchwork quilt, with differing nutrient applications on each small part of the site where a tanker truck dumps its load. In some cases then, the farmer has to over fertilize some portions of the field to assure that there are adequate nutrients for crop growth throughout the entire site.

Land Application Rates

In the handout is a simple form for calculating the amount of Nitrogen that you can apply to a site. The first step is to identify the crop that will be grown. The amount of nitrogen will be based on the crop grown and the expected loading. A number of crops also are dependent on the crop that was grown the previous year.

Using this information and the chart of page 5 the required nitrogen loading for the crop is established. This is given in pounds per acre. The chart on page 5 is for MN check with your local extension service for a better local resource.

The next step is to identify the other nitrogen sources. The first identified is the N available in the topsoil. If the organic matter is greater than 4.5% the amount of N available in the topsoil is 20 # per acre. The next source is fertilizer added by the farmer. The next is carry over from past septage applications. This is equal to 8 # per acre if septage was land applied last year. The final source would be other manure added to the site. This would be related to agricultural uses and a chart is given on page 6 of the handouts to calculate the amount of available N. All of these sources will reduce the amount of nitrogen that septage can apply.

The next step is the other givens. These include the specifics of your truck. How many gallons your tank can hold and how fast the tank will empty. Dividing these two numbers gives you the discharge rate in gallons per minute. The last truck detail is the width of the discharge behind your truck. If you open a 4" valve the factor would be .33' using a splash plate this value would be the width that is impacted, typically 8-12'.

The final given is the area that this site contains. This should be the actual area and the use of GPS can be handy in tracking use at the site.

The next the step will be calculating the actual amount of nitrogen that be supplied from the septage. This would be the amount needed minus all the existing sources. The Net allowable nitrogen in # per acre can be converted to septage by dividing 0.0026 # per gallon of septage.

The daily amount of septage must be les than 10,000 gallons per day. This is set in the 503 regulations to avoid over applying on any given day. To calculate this you should divide by an integer to reduce it below 10,000. This integer will be the number of trips necessary to proper load the site.

Once the daily limit is established the minimum speed that your truck must travel can be established. The speed is the rate that your truck empties times the conversion factor 495 divided by the product of the application width and the daily loading rate. This speed will be the minimum that your truck can move. The speed can be doubled meaning that the site will be applied twice as many times. A portable GPS can be useful for the truck to track the speed that the site can be loaded.

Soil Nutrient Requirements

Soil tests are useful to determine the crop nutrients available before the application of fertilizers. Soil tests can be done by state extension services and should be done every 2-4 years. The tests levels can vary throughout the year and the growing season therefore soil testing should be conducted at the same time of year and after the same crop if a rotation is used. The test results will provide a recommendation for application rates of nitrogen as N, phosphorous as P_2O_5, and potassium as K_2O.

To ease calculations, a conversion of P_2O_5 and K_2O to elemental P and K is helpful. To find the elemental P divide the amount of P_2O_5 by 2.27. Elemental K is found by dividing the amount of K_2O by 1.20.

$$P = \frac{P_2O_5}{2.27} \qquad\qquad K = \frac{K_2O}{1.20}$$

Example: How much elemental P and K are in 5 lbs of both P_2O_5 and K_2O?

P= 5/2.27 = 2.20 lbs K= 5/1.20 = 4.17 lbs

Biosolids Nutrient Composition

Just like the soils, septage samples can be sent to a lab for analysis to see concentrations of available nutrients in that specific source. Septage sample results should not change with human waste. . Samples could be taken as often as once per year. The 503 regulations include a constant as part of the calculation for land application; it is 0.0026 pounds of nitrogen per gallon of septage. The nutrient content for the waste sample will probably be reported in mass percentage of elemental N, P, and K so a conversion is not typically needed.

Crop Requirements

The nutrient concentration needs of the crop to be grown are very important. The amount of septage selected must be able to meet the needed nutrient concentration to be beneficial. The nutrient requirements using septage will be the same as if one were using chemical fertilizers. For example, according to the General Guide for Crop Nutrient Recommendation in Iowa, alfalfa grown in Iowa removes 50 pounds of N, 12.5 pounds of P_2O_5, and 40 pounds of K_2O per ton harvested. The USDA and state extension services have the nutrient requirements for crops for any area.

Nitrogen Losses

Nitrogen is subject to losses while waste materials are stored and applied. If the waste is stored in the open prior to land application, up to 50% of the nitrogen may be lost to volatilization of ammonia and transformation to gaseous nitrogen. (This may cause other issues with the site) The nitrogen in ammonium and urea can be lost into the atmosphere during and after the application also. During application, losses can be up to 40%. A correction factor is then used to account for this loss (Table 3).

Table 3 Application Method Correction Factors

Method	Correction Factor
Direct injection	0.98
Broadcast and incorporate within 24 hrs	0.95
Broadcast and incorporate after 24 hrs	0.80
Broadcast liquid, no incorporation	0.75

Broadcast dry, no incorporation	0.70
Irrigation, no incorporation	0.60

Iowa Department of Natural Resources

Plant Available Nitrogen

Once the nitrogen is in the field, it still is not completely available to plants as plant available nitrogen (PAN). Only about 50% of the nitrogen that reaches the field is considered PAN. Depending on the species that the waste came from, complete nitrogen availability does not occur until three years after application.

Nutrient Based Application Rates

After the waste calculations are completed, select one of the three major nutrients to base our application rate on. Nitrogen has long been used to determine biosolids application rates and is still used in most areas today. Phosphorous-based applications are becoming more frequent. Fertilizer runoff that contains high levels of unused phosphorus can be damaging to the environment[6]. The Bosque River in Texas is a perfect example of phosphorous runoff from agriculture and is currently being studied to ease the strain on the environment. Check with the local county agent or state regulatory agency to determine if phosphorous-based application rates are required for the area.

Calculations

Insert materials from Dave Gustafson on Pagemaker.

Pathogen and Vector Control

The most important concern is the pathogens; the potential for misapplied septage to make people sick. This is dealt with by treating the septage, and the 503 regulations lay out a number of treatment alternatives. The usual choice is the addition of lime to reduce or to remove the pathogens. The other options for treatment are heating or injection of the septage. Avoid wells and surface waters.

One choice that isn't currently included in the 503s is choosing good soil on which to land apply. By choosing the right soil, good removal of those pathogens could take place with the addition of lime, heating or injection.

Pathogen and Vector Attraction Reduction Choices

The applier has two choices for reducing pathogens in septage.

1) Do not treat the pumped domestic septage before land applying. Instead, ether directly inject this septage into the soil or incorporate it into the soil surface by plowing or disking within six hours after application. The applier must also assure that the landowner follows crop harvesting, animal grazing, and site access restrictions.

2) Adjust the pH of the domestic septage so that it remains at pH 12 or grater for at least 30 minutes before land applying. The applier must also assure that the landowner follows crop-harvesting restrictions.

The land applier must manage the domestic septage so that its attractiveness to vectors is reduced. There are three options: injection, incorporation, and pH adjustment. Note that pH adjustment will reduce both pathogens and attractiveness of septage to vectors.

Record Keeping for Septage

Record keeping is very important to verify the compliance with the regulations. 503 regulations require the land applier to maintain records of their activities. The following materials must be keeping meeting the record keeping requirements.

1. The location of the site where domestic septage is applied, either the street address, or the longitude and latitude of the site (available form the U.S. geological Survey maps).
2. The number of acres to which domestic septage is applied at each site.
3. The date and time of each domestic septage application.
4. The nitrogen requirement for the crop or vegetation grown on each site during the next year. Also, while not required, indicating the expected crop yield would help establish the nitrogen requirement.
5. The gallons of septage applied to the site during the specified 365-day period.
6. The following certification signed:

I certify under penalty of law, that the pathogen requirement alternative [insert 1 or 2] and the vector attraction reduction requirement alternative [insert 1, 2 or 3] have/have not [circle one] been met. This determination has been made under my direction and supervision in accordance with the system designed to assure that the qualified personnel properly gather and evaluate information used to determine that the pathogen requirements and vector attraction reduction requirements have been met. I am aware that there are significant penalties for false certification, including the possibility of fine and imprisonment.

7. A description of how the pathogen reduction requirements are met for each batch of domestic septage that is land applied.
8. A description of how the vector attraction reduction requirement is met for each batch of domestic septage that is land applied.

Summary

As with any other fertilizing technique, there are concerns with land application of septage. Public perception of septage is a large hurdle to get over before application. Over-application of the waste can lead to pollution of nearby waterways and environmental degradation. Extreme over-application may even cause plant toxicity. The applied wastes may contain salts that must be managed. Pathogenic bacteria can also be present in the waste. The balance of major nutrients in the waste may not match the balance of nutrients required by the crop. It may provide too much of one nutrient or not enough of another. The area required for proper disposal of wastes may exceed the land available to the producer. Carelessness can lead to non-uniform application. Through proper management and sound judgment, a producer can use nature's own fertilizer easily and safely.

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