

LD  
5655  
A762  
no. 452-  
300  
c. 2

# LAND APPLICATION OF BIOSOLIDS FOR AGRICULTURAL PURPOSES IN VIRGINIA

Virginia Cooperative Extension

a1002359241/b



VPI & SU LIBRARY



VIRGINIA POLYTECHNIC INSTITUTE  
AND STATE UNIVERSITY



VIRGINIA STATE UNIVERSITY



**LIBRARY** VIRGINIA  
POLYTECHNIC  
INSTITUTE  
AND  
STATE  
UNIVERSITY



# Land Application Of Biosolids For Agricultural Purposes In Virginia

*G.K. EVANYLO, DEPARTMENT OF CROP AND SOIL ENVIRONMENTAL SCIENCES, VIRGINIA TECH*

## What is the purpose of this bulletin?

This bulletin contains technical information on the practice of and regulations governing the agricultural use of biosolids. It is intended for use by local government officials; consultants and educators in disciplines such as environmental engineering, land use, soils, agronomy, and horticulture; and concerned citizens of the Commonwealth of Virginia. The information in this bulletin should enable citizens to better assess the advantages and disadvantages of land applying biosolids for agriculture.

## What is the scope of this bulletin?

This publication provides background information and guidelines on the proper use of biosolids on cropland and pastureland and an overview of the regulations governing its use. Some controversy exists as to the safety to the environment and human health from long term application of biosolids; however, it is beyond the scope of this publication to assess the protectiveness of the federal and state regulations governing the land application of biosolids or the effectiveness of the regulatory agencies in carrying out their responsibilities.

This bulletin does not provide specific information on the application of biosolids for forest land, reclamation sites (mines spoils, construction sites, gravel pits), or public contact sites (such as parks and golf courses), lawns, and home gardens, although much of the general information presented in this publication applies to all of the above. Further information on these practices may be obtained from the EPA publication Process Design Manual: Land Application of Sewage Sludge and Domestic Septage (U.S. EPA, 1995a).

## Acknowledgments

The author wishes to thank the following individuals and organizations for providing critical comments during the preparation of this publication: Rick Stehouwer, Penn State University; Daniel Kluchinski, Rutgers University; Charles Hagedorn and James Baker, Virginia Tech; Robert Clark, Philip Schroeder, James Riddell, and Steven Hopkins, Virginia Cooperative Extension; Calmet Sawyer, Virginia Department of Health; Lily Choi, Virginia Department of Environmental Quality; Russ Perkinson, Virginia Department of Conservation and Recreation; Hunter Richardson, Virginia Department of Agriculture and Consumer Services; Sharon Hogan, Waste Management, Inc., Bio Gro Division; William Keeling; Consultant; Rhonda Bowen, Hampton Roads Sanitation Department; and D.W. Burruss, II, Shenandoah County Alliance Against Toxic Sludge, LLC.

Funding for this publication was provided by the Virginia Department of Conservation and Recreation and by the United States Department of Agriculture Cooperative State Research, Education, and Extension Service.



# Contents

---

<b>Chapter 1. Introduction</b> . . . . .	<b>1</b>
What are biosolids and how are they different from sewage sludge? . . . . .	1
How are biosolids produced? . . . . .	1
Characterization of Biosolids . . . . .	3
<b>Chapter 2. Beneficial Use/Disposal Options</b> . . . . .	<b>5</b>
Landfill disposal . . . . .	5
Incineration . . . . .	5
Land application (beneficial use) . . . . .	5
<b>Chapter 3. Biosolids Land Application Regulations</b> . . . . .	<b>7</b>
Federal regulations . . . . .	7
Pollutants . . . . .	7
Organic chemicals . . . . .	7
Pathogen reduction . . . . .	8
Vector attraction reduction . . . . .	9
Categories of biosolids quality . . . . .	9
Nutrients . . . . .	9
State regulations . . . . .	9
Other regulatory considerations . . . . .	11
Site suitability . . . . .	11
Landowner agreements . . . . .	12
<b>Chapter 4. Risks and Concerns of Land Application of biosolids</b> . .	<b>13</b>
Disadvantages of land application . . . . .	13
Human health and environmental risks . . . . .	13
Risk assessment approach to regulation . . . . .	13
Part 503 risk assessment . . . . .	14
Alternative regulatory approaches . . . . .	15
Best available technology . . . . .	15
Non-contamination approach . . . . .	15
Pathogen regulation . . . . .	16
Can biosolids be used safely? . . . . .	16
Future directions . . . . .	16
Conclusions . . . . .	16



## **Chapter 5. Applying and Managing Biosolids on Agricultural Land .17**

Determining nutrient needs . . . . .	.17
Determining agronomic rates . . . . .	.17
Why are biosolids' applications usually based on crop N needs? . . . . .	.18
What is PAN and how is it determined? . . . . .	.18
How are the availabilities of the different forms of N in biosolids determined? . . . . .	.18
Will agronomic N rates of biosolids meet crop needs of all nutrients? . . . . .	.19
How are the plant availabilities of P and K from biosolids determined? . . . . .	.19
What problems may be caused by applying biosolids at agronomic N rates? . . . . .	.19
Can the proper biosolids application rate be determined by other fertility parameters? . . . . .	.19
Determining supplemental fertilizer needs . . . . .	.20
Selection of suitable crops for fertilization with biosolids . . . . .	.20
Application methods . . . . .	.20
Timing of biosolids application . . . . .	.21
Biosolids storage . . . . .	.21

## **Chapter 6. Commonly Asked Questions . . . . .22**

Who can provide information about the permitting process for land application? . . . . .	.22
What are the normal steps for approval of land application of biosolids in a Virginia county? . . . . .	.22
Who is responsible for collecting information, obtaining approval, and properly . . . . .	.22
applying the material?	
Who is responsible for recordkeeping and reporting? . . . . .	.22
Who assumes liability for improper management of biosolids? . . . . .	.22
How can good biosolids management be ensured? . . . . .	.23

## **References . . . . .24**





### What are biosolids and how are they different from sewage sludge?

Biosolids are solid, semi-solid or liquid materials, resulting from treatment of domestic sewage, that have been sufficiently processed to permit these materials to be safely land-applied. The term was introduced by the wastewater treatment industry in the early 1990's and has been recently adopted by the United States Environmental Protection Agency (U.S. EPA) to distinguish high quality, treated sewage sludge from raw sewage sludge and from sewage sludge containing large amounts of pollutants. Some groups have charged that the term "biosolids" has been employed to disguise the real nature of sewage sludge from the general public, thereby reducing objections to land application of sewage sludge. Although "biosolids" does not evoke the same negative connotation as does "sewage sludge," the use of the term is appropriate when it makes the distinction described above.

### How are biosolids produced?

Biosolids are produced primarily through biological treatment of domestic wastewater (Fig. 1.1). Physical and chemical processes are often employed additionally to improve the biosolids handling characteristics, increase the economic viability of land application, and reduce the potential for public health, environmental and nuisance problems associated with land application practices. These processes sanitize wastewater treatment solids to control disease-causing organisms and reduce characteristics that might attract rodents, flies, mosquitoes, or other organisms capable of transporting infectious disease. The type and extent of processes used to treat wastewater will affect the degree of pathogen reduction attained and the potential for odor generation. Common treatment processes and their effects on biosolids properties and land application practices are summarized in Table 1.1.

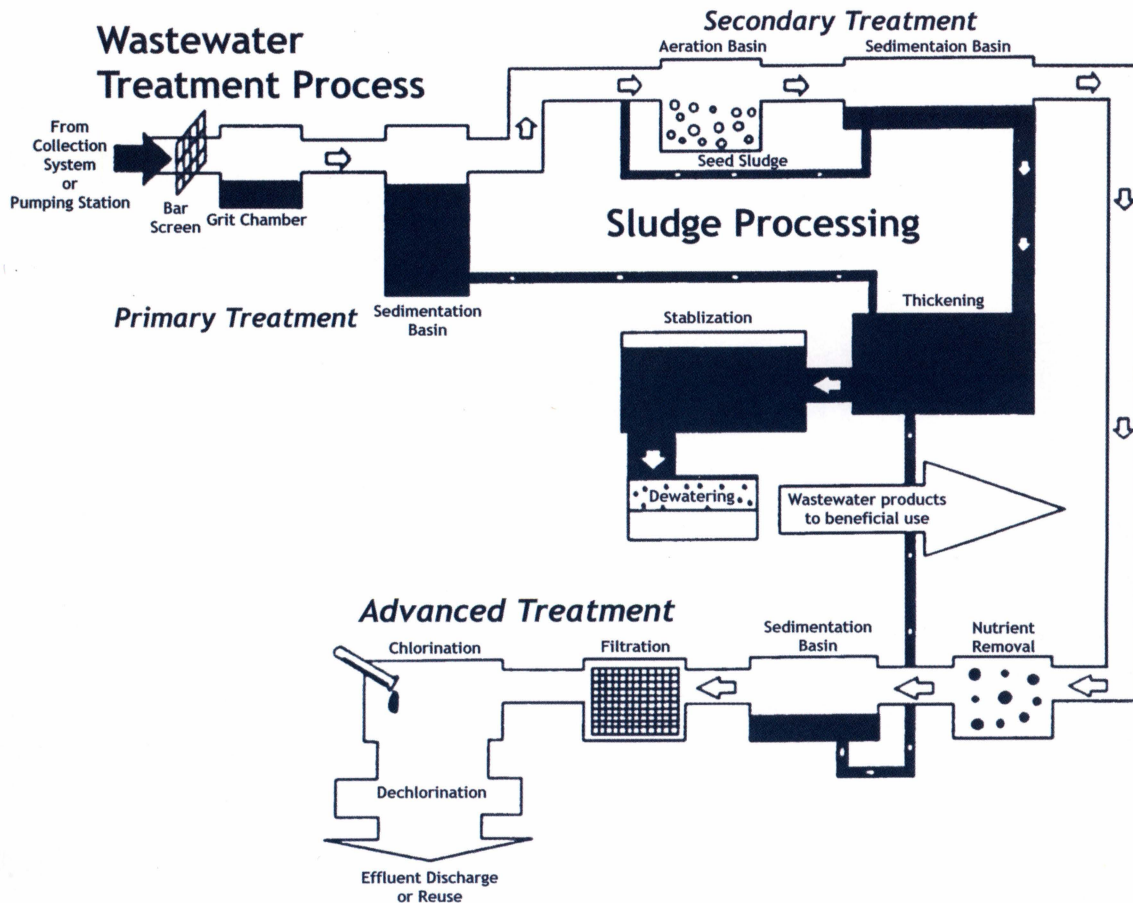


Fig 1.1: Schematic of wastewater treatment facility



**Table 1.1**

Effects of biosolids treatment processes on land application practices (Adapted from U.S. EPA, 1984).

<b>Treatment Process and Definition</b>	<b>Effect on Biosolids</b>	<b>Effect on Land Application Practices</b>
<b>Thickening:</b> Low force separation of water and solids by gravity, flotation, or centrifugation.	Increases solids content by removing water.	Lowers transportation costs.
<b>Digestion (anaerobic and aerobic):</b> Biological stabilization through conversion of organic matter to carbon dioxide, water, and methane.	Reduces the biodegradable content (stabilization) by conversion to soluble material and gas. Reduces pathogen levels and odor.	Reduces the quantity of biosolids.
<b>Alkaline stabilization:</b> Stabilization through the addition of alkaline materials (e.g., lime, kiln dust).	Raises pH. Temporarily decreases biological activity. Reduces pathogen levels and controls putrescibility and odor.	High pH immobilizes metals as long as pH levels are maintained.
<b>Conditioning:</b> Processes that cause biosolids to coagulate to aid in the separation of water.	Improves sludge dewatering characteristics. May increase dry solids mass and improve stabilization.	The ease of spreading may be reduced by treating biosolids with polymers.
<b>Dewatering:</b> High force separation of water and solids. Methods include vacuum filters, centrifuges, filter and belt presses, etc.	Increases solids concentration to 15% to 45%. Lowers nitrogen and potassium concentrations. Improves ease of handling.	Reduces land requirements and lowers transportation costs.
<b>Composting:</b> Aerobic, thermophilic, biological stabilization in a windrow, aerated static pile or vessel.	Lowers biological activity, destroys pathogens, and converts sludge to humus-like material.	Excellent soil conditioning properties. Contains less plant available nitrogen than other biosolids.
<b>Heat drying:</b> Use of heat to kill pathogens and eliminate most of the water content.	Disinfects sludge, destroys most pathogens, and lowers odor and biological activity.	Greatly reduces sludge volume.



## Characterization of biosolids

The suitability of a biosolid for land application can be assessed by biological, chemical, and physical analyses. Biosolids' composition depends on wastewater constituents and treatment processes. The resulting properties will determine application method and rate, and the degree of regulatory control required. Several of the more important properties of biosolids are discussed below.

Total solids (TS) include suspended and dissolved solids and are usually expressed as the concentration present in biosolids. TS depend on the type of wastewater process and biosolids' treatment prior to land application. Typical solids contents of various biosolids' processes are: liquid (2-12%), dewatered (12-30%), and dried or composted (50%).

**Volatile solids (VS)** provide an estimate of the readily decomposable organic matter in biosolids and are usually expressed as a percentage of total solids. VS are an important determinant of potential odor problems at land application sites. A number of treatment processes, including anaerobic digestion, aerobic digestion, alkaline stabilization, and composting, can be used to reduce VS content and, thus, the potential for odor.

**pH** is a measure of the degree of acidity or alkalinity of a substance. The pH of biosolids is often raised with alkaline materials to reduce pathogen content and attraction of disease-spreading organisms (vectors). High pH (greater than 11) kills virtually all pathogens and reduces the solubility, biological availability and mobility of most metals. Lime also increases the gaseous loss (volatilization) of the ammonia (NH<sub>3</sub>) form of nitrogen (N), thus reducing the N-fertilizer value of biosolids.

**Pathogens** are disease-causing microorganisms that include bacteria, viruses, protozoa, and parasitic worms. Pathogens can present a public health hazard if they are transferred to food crops grown on land to which biosolids are applied; contained in runoff to surface waters from land application sites; or transported away from the site by vectors such as insects, rodents, and birds. For this reason, federal and state regulations specify pathogen and vector attraction reduction requirements that must be met by biosolids applied to land. A partial list of pathogens that can be found in untreated sewage sludge and the diseases or symptoms that they can cause are presented in Table 1.2.

**Nutrients** are elements required for plant growth that provide biosolids with most of their economic

**Table 1.2**

A partial list of pathogens that can be found in municipal wastewater and solids and diseases or symptoms they cause (adapted from U.S. EPA, 1995).

Organism	Disease/Symptoms
<b>Bacteria</b>	
Salmonella sp.	Salmonellosis (food poisoning), Typhoid fever
Escherichia coli	Gastroenteritis
Shigella sp.	Bacillary dysentery, severe gastroenteritis
<b>Enteric Viruses</b>	
Hepatitis A virus	Infectious hepatitis
Echoviruses	Meningitis, paralysis, encephalitis, fever, "flu-like" symptoms, diarrhea, etc.
<b>Protozoa</b>	
Entamoeba histolytica	Amoebic dysentery
Giardia lamblia	Diarrhea, abdominal cramps, weight loss
<b>Helminth Worms</b>	
Ascaris sp.	Digestive and nutritional disturbances, abdominal pain, vomiting, restlessness, coughing, chest pain, and fever
Trichuris trichiura	Abdominal pain, diarrhea, anemia, weight loss
Toxocara canis	Fever, muscle aches, neurological symptoms
Necator americanus	Hookworm disease



value. These include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulfur (S), boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). Concentrations in biosolids can vary significantly (Table 1.3); thus, the actual material being considered for land application should be analyzed.

**Trace elements** are found in low concentrations in biosolids. The trace elements of interest in biosolids are those commonly referred to as “heavy metals.” Some of these trace elements (e.g., copper, molybdenum, and zinc) are nutrients needed for plant growth in low concentrations, but all of these elements can be toxic to humans, animals, or plants at high concentrations. Possible hazards associated with a build up of trace elements in the soil include their potential to cause phytotoxicity (i.e., injury to plants) or to

increase the concentration of potentially hazardous substances in the food chain. Federal and state regulations have established standards for the following nine trace elements: arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn).

**Organic chemicals** are complex compounds that include man-made organic chemicals from industrial wastes, household products, and pesticides. It is possible to analyze specific organic compounds in biosolids, but most are found at such low concentrations that the EPA concluded they do not pose significant human health or environmental threats. Although no organic pollutants are included in the current federal biosolids regulations, further assessment of several specific organic compounds (e.g., dioxins, PCBs) is being conducted.

**Table 1.3**

Typical nutrient concentrations<sup>a</sup> in biosolids from all processes<sup>b</sup> (adapted from Sommers, 1977)

Nutrient	No. of samples	Range	Mean
Total N (%)	191	<0.1-17.6	3.9
NH <sub>4</sub> -N (%)	103	0.0005-6.7	0.65
NO <sub>3</sub> -N (%)	45	0.0002-0.49	0.05
Total P (%)	189	<0.1-14.3	2.5
K (%)	192	0.02-2.64	0.40
Ca (%)	193	0.1-25.0	4.9

<sup>a</sup> Concentrations are on a dried solids basis.

<sup>b</sup> Processes include anaerobically and aerobically digested, lagooned, primary, tertiary, and unspecified biosolids.



Biosolids can be considered as a waste to be disposed of or as a beneficial soil amendment. Ocean dumping, a disposal practice common in the 1980's, was banned due to concerns about excess nutrient loading in these waters. Presently, about half of the biosolids generated in Virginia are applied to land and the remainder are disposed of through landfilling or incineration.

### Landfill disposal

Landfill disposal offers the simplest solution to biosolids handling by concentrating the material in a single location. The risk of release of biosolids-borne pollutants and pathogens is minimal if the landfill is properly constructed and maintained. Economically, the cost compares favorably with other options.

Landfill disposal is not, however, without risks. Buried organic wastes undergo anaerobic decomposition which produces methane gas. Methane is a greenhouse gas whose release to the atmosphere has been implicated in possible global warming. The chemicals and nutrients can pose risk to local groundwater from older landfills that do not have synthetic liners or from a liner in a newer landfill developing a leak. In addition, the potential benefits of the organic matter and plant nutrients in the biosolids are lost with landfilling.

### Incineration

Incineration reduces the biosolids volume, kills pathogens, destroys most organic chemicals, and provides energy. The remaining ash is a stable, relatively inert, inorganic material that possesses 10 to 20 percent of the original volume. Trace elements are not destroyed during incineration, which increases their concentrations in the ash by five to ten-fold.

Incineration releases carbon dioxide (another greenhouse gas). Incineration is one of the more expensive options for biosolids disposal because it requires sophisticated systems to remove fine particulate matter (fly ash) and volatile pollutants from stack gases. Furthermore, the ash containing the higher trace element concentrations must usually be landfilled. As with landfilling, the potential benefits of organic matter and plant nutrient recycling are lost.

### Land application (beneficial use)

As an alternative to disposal by landfilling or incineration, land application seeks to beneficially recycle

the soil property-enhancing constituents in biosolids, which are derived from crops grown on agricultural land. Biosolids are about 50 percent mineral and 50 percent organic matter. The mineral matter includes plant nutrients, and organic matter is a source of slow release nutrients and soil conditioners. Land application returns those materials to the soil where they can contribute to further crop production.

Farmers can benefit from biosolids application by reducing fertilizer costs. The main fertilizer benefits are through the supply of nitrogen, phosphorus and lime (where lime-stabilized biosolids are applied). Biosolids also ensure against unforeseen nutrient shortages by supplying essential plant nutrients that are rarely purchased by farmers because crop responses to their application is unpredictable. These include elements such as sulfur, manganese, zinc, copper, iron, molybdenum, and boron.

Land application replenishes valuable organic matter, which occurs in less than optimum amounts in most Virginia soils. The addition of organic matter can improve soil tilth, the physical condition of soil as related to its ease of tillage, fitness as a seedbed, and its impedance to seedling emergence and root penetration. Other benefits imparted by the addition of organic matter to soil include:

- increases water infiltration into the soil and soil moisture-holding capacity
- reduces soil compaction
- increases the ability of the soil to retain and provide nutrients
- reduces soil acidification
- provides an energy source (carbon) for beneficial microorganisms

The addition of organic matter in biosolids to a fine-textured clay soil can help make the soil more friable and can increase the amount of pore space available for root growth and entry of water and air into the soil. In coarse-textured sandy soils, organic residues in biosolids can increase the water-holding capacity of the soil and provide chemical sites for nutrient exchange and adsorption.

Land application is usually less expensive than alternative methods of disposal. Consequently, wastewater treatment facilities and the public they serve benefit through cost savings. The recycling of nutrients and organic matter can be attractive to citizens concerned with environmental protection and resource conservation.



Land application of biosolids involves some risks, which are addressed through federal and state regulatory programs. Pollutants and pathogens are added to soil with organic matter and nutrients. Human and animal health, soil quality, plant growth and water quality could be adversely affected if land application is not conducted in an agronomically and environmentally sound manner. In addition, nitrogen and phosphorus in biosolids, as in any fertilizer source, can contaminate ground and surface water if the material is overapplied or improperly applied. There are risks and benefits to each method of biosolids disposal and use. The following chapters will provide information to aid in the assessment of the land application option.

As required by the Clean Water Act Amendments of 1987, the U.S. Environmental Protection Agency (EPA) developed the regulation, The Standards for the Use or Disposal of Sewage Sludge (Title 40 of the Code of Federal Regulations [CFR], Part 503). The Part 503 rule establishes minimum requirements when biosolids are applied to land to condition the soil or fertilize crops or other vegetation grown in the soil. The Clean Water Act required that this regulation protect public health and the environment from any reasonably anticipated adverse effects of pollutants and pathogens in biosolids.

Federal regulations require that state regulations be at least as stringent as the Part 503 rule. The Biosolids Use Regulations (12 VAC 5-585, 32.1-164.5 of the Code of Virginia), which regulate the agricultural use of biosolids in Virginia, were developed by the Virginia Department of Health for contractors who land apply, distribute, or market biosolids. Other State agencies also have roles in the biosolids use program in Virginia. The Department of Environmental Quality issues Pollutant Discharge Elimination System (VPDES) permits to owners of wastewater treatment facilities that land apply their own biosolids. Staff of the Department of Conservation and Recreation review the permits' nutrient balance sheets and nutrient management plans, and personnel from the Department of Environmental Quality and Department of Agriculture and Consumer Services provide input into regulation development and review. Local governments may enact ordinances that place further restrictions on land application practices.

The underlying premise of both the Federal and State regulations is that biosolids should be used in a manner that limits risks to human health and the environment. The regulations prohibit land application of low-quality sewage sludge and encourage the application of biosolids that are of sufficient quality that they will not adversely affect human health or the environment. Determination of biosolids quality is based on trace element (pollutant) concentrations and pathogen reduction.

### Federal Regulations

#### Pollutants

The Part 503 rule prohibits land application of sewage sludge that exceeds certain limits (Table 3.1) for nine trace elements, including arsenic, cadmium,

copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Such materials could not be applied to land and are not considered biosolids. The *ceiling concentration limits* are the maximum concentrations of the nine trace elements allowed in biosolids to be land applied. Biosolids exceeding the ceiling concentration limit for even one of the regulated pollutants cannot be land applied.

*Pollutant concentration limits* are the most stringent pollutant limits included in Part 503 for land application. Biosolids meeting pollutant concentration limits are subject to fewer requirements than biosolids meeting ceiling concentration limits. Results of the U.S. EPA's 1990 National Sewage Sludge Survey (NSSS) [U.S. EPA, 1990] demonstrated that the mean concentrations of the nine regulated pollutants are considerably lower than the most stringent Part 503 pollutant limits (Table 3.1).

The *cumulative pollutant loading rate* (Table 3.1) is the total amount of a pollutant that can be applied to a site in its lifetime by all bulk biosolids applications meeting ceiling concentration limits. No additional biosolids meeting ceiling concentration limits can be applied to a site after the maximum cumulative pollutant loading rate is reached at that site for any one of the nine regulated trace elements. Only biosolids that meet the more stringent pollutant concentration limits may be applied to a site once a cumulative pollutant loading rate is reached at that site.

In 1978 the EPA established pretreatment specifications (40 CFR Part 403) that require industries to limit the concentrations of certain pollutants, including trace elements and organic chemicals, in wastewater discharged to a treatment facility. The improvement in the quality of biosolids over the years has largely been due to pretreatment and pollution prevention programs (Shimp, et al., 1994).

#### Organic chemicals

Part 503 does not regulate organic chemicals in biosolids because the organic chemicals of potential concern have been banned or restricted for use in the United States; are no longer manufactured in the United States; are present at low concentrations based on data from EPA's 1990 NSSS [U.S. EPA, 1990]; or because the limit for an organic pollutant identified in the Part 503 risk assessment is not expected to be exceeded in biosolids that are land applied (U.S. EPA, 1992a). Restrictions will be imposed for agricultural



use if testing of certain toxic organic compounds verifies that biosolids contain levels that could cause harm to human health or the environment.

### Pathogen reduction

Federal and state regulations require the reduction of potential disease-causing microorganisms, called pathogens (e.g., viruses, bacteria and parasitic worms) and vector (e.g., rodents, birds, insects that can transport pathogens away from the land application site) attraction properties. Biosolids intended for land application are normally treated by chemical or biological processes that greatly reduce the number of pathogens and odor potential in sewage sludge. Two levels of pathogen reduction, Class A and Class B, are specified in the regulations.

The goal of Class A requirements is to reduce the pathogens (including *Salmonella* sp., bacteria, enteric viruses, and viable helminth ova) to below detectable levels. Class A biosolids can be land applied without any pathogen-related site restrictions. *Processes to further reduce pathogens* (PFRP) treatment, such as those involving high temperature, high pH with alkaline

addition, drying, and composting, or their equivalent are most commonly used to demonstrate that biosolids meet Class A requirements.

The goal of Class B requirements is to ensure that pathogens have been reduced to levels that are unlikely to cause a threat to public health and the environment under specified use conditions. *Processes to significantly reduce pathogens* (PSRP), such as digestion, drying, heating, and high pH, or their equivalent are most commonly used to demonstrate that biosolids meet Class B requirements.

Because Class B biosolids contain some pathogens, certain site restrictions are required. These are imposed to minimize the potential for human and animal contact with the biosolids until environmental factors (temperature, moisture, light, microbial competition) reduce the pathogens to below detectable levels (Table 3.2). The site restriction requirements in combination with Class B treatment are expected to provide a level of protection equivalent to Class A treatment. All biosolids that are land applied must, at a minimum, meet Class B pathogen reduction standards.

**Table 3.1**

Land applied biosolids pollutant limits (Adapted from U.S. EPA, 1995) and mean concentrations (NSSS) from National Sewage Sludge Survey (U.S. EPA, 1990).

Pollutant	CCL <sup>a,b</sup> ppm <sup>f</sup>	PCL <sup>a,c</sup> ppm	CPLR <sup>a,d</sup> lbs/acre	NSSS <sup>a</sup> ppm
Arsenic (As)	75	41	36	10
Cadmium (Cd)	85	39	35	7
Copper (Cu)	4300	1500	1340	741
Lead (Pb)	840	300	270	134
Mercury (Hg)	57	17	16	5
Molybdenum (Mo)	75	e	e	9
Nickel (Ni)	420	420	375	43
Selenium (Se)	100	100	89	5
Zinc (Zn)	7500	2800	2500	1202

<sup>a</sup> Dry weight basis.

<sup>b</sup> CCL (ceiling concentration limits) = maximum concentration permitted for land application.

<sup>c</sup> PCL (pollutant concentration limits) = maximum concentration for biosolids whose trace element pollutant additions do not require tracking (i.e., calculation of CPLR).

<sup>d</sup> CPLR (cumulative pollutant loading rate) = total amount of pollutant that can be applied to a site in its lifetime by all bulk biosolids applications meeting CCL.

<sup>e</sup> The February 25, 1994 Part 503 Rule amendment deleted Mo PCL for sewage sludge applied to agricultural land but retained Mo CCL.

<sup>f</sup> ppm = part per million.



**Table 3.2**

Class B biosolids application land use restrictions (VDH, 1997).

Root crops, where biosolids remain on land surface:		
	≥ 4 mos. prior to soil incorporation	Harvest 20 months after application
	< 4 mos. prior to soil incorporation	Harvest 38 months after application
Food crops that touch biosolids or soil		Harvest 14 months after biosolids application
Other food, feed or fiber crops		Harvest 30 days after application
Turf		Harvest 1 year after application when the turf is placed on land with high potential for public exposure
Grazing animals		
	Lactating (milking) animals	No grazing prior to 30 days after application
	Non-lactating animals	No grazing prior to 60 days after application
Public access to land		
	High access potential	Restricted to 1 year after application
	Low access potential	Restricted to 30 days after application

### Vector attraction reduction

The objective of vector attraction reduction is to prevent disease vectors such as rodents, birds, and insects from transporting pathogens away from the land application site. There are ten options available to demonstrate that land-applied biosolids meet vector attraction reduction requirements. These options fall into either of the following two general approaches: 1) reducing the attractiveness of the biosolids to vectors with specified organic matter decomposition processes (e.g., digestion, alkaline addition) and 2) preventing vectors from coming into contact with the biosolids (e.g., biosolids injection or incorporation below the soil surface within specified time periods).

### Categories of biosolids quality

The quality of biosolids (i.e., pollutant concentrations, pathogen levels, and vector attraction reduction control) determines which land application requirements must be met. There are three categories of biosolids quality that are discussed below and described in Table 3.3.

Biosolids that meet the Part 503 PCLs, Class A pathogen reduction, and a vector attraction reduction option that reduces organic matter are classified as “*exceptional quality*” or EQ biosolids. In general, EQ biosolids can be applied as freely as any other fertilizer or soil amendment to any type of land. Virginia requires additional recordkeeping for distribution of bulk quantities and specific labeling information for bagged products marketed under a registration filed with the Virginia Department of Agriculture and Consumer Services.

*Pollutant concentration (PC)* biosolids meet the same low pollutant limits (PCLs) as EQ biosolids, but PC biosolids usually meet Class B rather than Class A pathogen reduction requirements. Biosolids meeting Class A pathogen reduction requirements plus one of the practices designed to prevent vectors from coming into contact with biosolids also are PC biosolids.

*Cumulative pollutant loading rate (CPLR)* biosolids, unlike EQ or PC biosolids, require tracking of the cumulative metal loadings to ensure adequate protection of public health and the environment.

### Nutrients

Federal regulations specify that biosolids may only be applied to agricultural land at or less than the rate required to supply the nitrogen (N) needs of the crops to be grown. This “agronomic rate” is “designed: (1) to provide the amount of N needed by the food crop, feed crop, fiber crop, or vegetation grown on the land; and (2) to minimize the amount of N in the biosolids that passes below the root zone of the crop or vegetation grown on the land to the ground water (40 CFR 503.11 (b)).” Agronomic rate may also be based on crop phosphorus (P) needs if it is determined that excessive soil P poses a threat to water quality. By signing the land application agreement with a biosolids contractor, the farmer is obligated to make every reasonable attempt to produce a crop on sites receiving biosolids that matches the agronomic rate applied.

### State Regulations

The Virginia Department of Health regulations were enacted to establish state- and site-specific management



practice standards, which are more demanding than the Part 503 rule. The Biosolids Use Regulations were developed to protect public health from improper and unregulated disposal of sewage and sewage sludge. Discharge of improperly treated and unacceptable quality sewage sludge could result in pollution of surface and groundwater, contamination of soil and exposure of the public to infectious agents. The regulations define current standards of practice and the technical design standards and operational requirements to ensure that new or upgraded biosolids use facilities provide the capacity and/or performance reliability necessary to comply with permit requirements. Some of the specific requirements of the state regulations include:

- Infrequent (once every three years) agronomic rate application is encouraged by imposing additional nutrient management planning and monitoring requirements on land amended with agronomic rates of biosolids on a frequent (annual) basis. Biosolids may be applied frequently (annually) at “below agronomic rates” without additional monitoring as

long as residual nutrients are accounted for in the management plan. These practices have been specified in order to control the buildup of soil phosphorus and residual nitrogen. Infrequent application also reduces the addition of pollutants (metals) to the soil, thus increasing the time that biosolid applications take to reach the cumulative pollutant loading rate.

- Biosolids loading rate can be limited by soil pH when biosolids containing appreciable amounts of lime are applied. High soil pH values caused by excessive liming can result in micronutrient deficiencies in crops grown in such soils. The soil pH should be no greater than 6.5 for Coastal Plain soils and 6.8 for soils in other regions of the state for sensitive crops.
- The Virginia Department of Conservation and Recreation may require the preparation of a complete nutrient management plan or soil conservation plan if sites exhibiting a soil test phosphorus concentration of  $\geq 55$  ppm phosphorus (Mehlich I analytical test procedure or the equivalent) pose

**Table 3.3**  
Summary of requirements for different quality bulk biosolids.

Biosolids Type	Ceiling Concentration Limit	Other Pollutant Limits	Pathogen Class	Vector Attraction Reduction <sup>a</sup>	Siting Restrictions	Track Added Pollutant	Required Management Practices
Exceptional Quality (EQ)	Yes	Pollutant Conc Limits	A	Treatment Options	No	No	No <sup>b</sup>
Pollutant Concentration (PC)	Yes	Pollutant Conc Limits	A or B	Any Option	No <sup>a</sup> Yes <sup>b</sup>	No	Yes <sup>c</sup>
Cumulative Pollutant Loading Rate (CPLR)	Yes	Cumulative Pollutant Loading Rate	A or B	Any Option	Yes	Yes	Yes

<sup>a</sup> The eight vector attraction reduction treatment options that reduce the attractiveness of the biosolids to vectors by further decomposition of the volatile solids. Two additional management options (incorporation and injection) prevent vectors from coming into contact with the biosolids.

<sup>b</sup> EQ biosolids can be applied as freely as any other fertilizer or soil amendment to any type of land. Virginia requires additional recordkeeping for distribution of bulk quantities and specific labeling information for bagged products marketed under a registration filed with the Virginia Department of Agriculture and Consumer Services. EQ biosolids are exempt from Part 503 general requirements and management practices.

<sup>c</sup> Management practices are required when biosolids do not meet EQ criteria either because they meet vector attraction reduction through soil injection or incorporation.



significant erosion potential based on site soils and topography. Such sites are not good candidates for biosolids application without additional management practices.

- Specified best management practices (BMPs) must be used if biosolids are applied to slopes greater than five percent between November 16 of one year and March 15 of the following year. Biosolids should be directly injected into soils on sites exhibiting erosion potential unless other BMPs are used to minimize soil erosion and the potential of nonpoint runoff. Biosolids may not be applied to site slopes exceeding 15 percent. Biosolids must be directly injected or incorporated within 48 hours if: 1) applied on sites with less than 60 percent uniform residue cover within any portion of the site, or 2) applied to soils during periods when soils may be subject to frequent flooding.
- Biosolids may only be applied to snow-covered ground if the snow cover does not exceed one inch and if the snow and biosolids are incorporated within 24 hours of application. Liquid sludges may not be applied to frozen ground. Dry or dewatered biosolids may be applied to frozen ground only if the site slope is five percent or less, a 200 foot vegetative buffer is maintained from surface water courses, and the entire application site has uniform vegetative coverage of at least 60 percent.
- The BURs specify minimum distances to land application areas from occupied dwellings, water supply wells or springs, property lines, perennial streams and other surface waters, intermittent streams/-drainage

ditches, improved roadways, rock outcrops and sinkholes, and agricultural drainage ditches (Table 3.4). Standard buffer distances to perennial streams and other surface waters must be doubled if site slopes are greater than 7 percent and when applied between November 16 and December 21.

## Other Regulatory Considerations

### Site suitability

Site physical characteristics that influence the land application management practices include: topography; soil permeability, infiltration, and drainage patterns; depth to groundwater; and proximity to surface water. Federal, state, and local regulations, ordinances or guidelines place limits on land application based on these physical characteristics. Potentially unsuitable areas for biosolids application include: 1) areas bordered by ponds, lakes, rivers, and streams without appropriate buffer areas; 2) wetlands and marshes; 3) steep areas with sharp relief; 4) undesirable geology (karst, fractured bedrock) if not covered by a sufficiently thick layer of soil; 5) undesirable soil conditions (rocky, shallow); 6) areas of historical or archeological significance; and 6) other environmentally sensitive areas, such as floodplains.

Application sites should possess good tilth, moderate to high surface infiltration rates and moderate to slow subsoil permeability. The Virginia BURs require at least 18 inches to bedrock or restrictive layers and to seasonal water table, and a soil pH of 6.0 or higher

**Table 3.4**

Minimum distances (feet) to land application area.

Adjacent feature	Surface Application <sup>a</sup>	Incorporation	Winter <sup>b</sup>
Occupied dwellings	200	200	200
Water supply wells or springs	100	100	100
Property lines	100	50	100
Perennial streams and other surface water, except intermittent streams	50	35	100
Intermittent streams/drainage ditches	25	25	50
All improved roadways	10	5	0
Rock outcrops and sinkholes	25	25	25
Agricultural drainage ditches with slopes equal to or less than 2%	10	5	10

<sup>a</sup> Not plowed or disced to incorporate within 48 hours.

<sup>b</sup> Application occurs on average site slope greater than 7% during period between November 16 of one year and March 15 of the following year.



at the time of application if the cadmium concentration in the biosolids is greater than 21 ppm.

### **Landowner Agreements**

In addition to the requirements of state and local permits, farmers have the right to negotiate with the biosolids applicator regarding how they want land application spreading operations to be conducted in their property. A written agreement covering such items as location of fields that will receive biosolids, crop rotations, seasons when spreading will take place, identification of truck entrances and exits, method of application, and any restrictions, such as prohibiting spreading when soils are too wet, may be useful.



Vegetative buffer strips separate biosolids from edge of field, drainage ditches, rock outcrops, etc.

(Photograph courtesy of Nutri-Blend, Inc.)

### Disadvantages of land application

Large land areas may be needed for agricultural use of biosolids because application rates are relatively low. Transportation and application scheduling that is compatible with agricultural planting, harvesting, and possible adverse weather conditions require careful management.

Biosolids, even when properly treated, will have odors. Under unfavorable weather conditions, the odors may be objectionable, even to rural communities accustomed to manure spreading operations. Odors may be reduced by stabilization process, application method, storage type, climatological conditions, and site selection as described below.

- Stabilization produces less odorous and biologically active biosolid. The products of aerobic digestion, heat treatment, and composting tend to result in the least objectionable odors. Anaerobic digestion has the potential to cause more odor than other treatment methods if not performed properly. Likewise, lime-stabilized biosolids, the most commonly used material in the state, may generate odors if not properly stabilized and managed.
- Application method affects the odor potential at the site. Immediate soil incorporation or direct soil injection reduce the potential for odor problems.
- Biosolids storage can occur at the treatment plant, the site of application, or a temporary facility. Storage at the treatment plant (if isolated from the public) is the preferred method. Off-site storage requires proper site selection and management to minimize the potential for odor problems.
- Weather conditions (i.e., temperature, relative humidity, wind) will affect odor severity when biosolids are surface-applied. Spreading in the morning when air is warming and rising will help dilute the odor in the immediate vicinity.
- The selection of the application site is important to the success of the operation. Ideally, the site should be located away from residential areas. Objectionable odors will sometimes be present despite adequate stabilization processes and favorable weather conditions. Complaints can be expected if adjacent property owners are subjected to persistent odors. A well-managed system with the proper equipment and stabilized biosolid will substantially reduce the potential for unacceptable odors.

Biosolids are typically delivered to the application site by tractor trailers that haul approximately 20 tons. At a solids content of 15-25 percent, this is approximately 3-5 dry tons per trailer, or about the amount of biosolids that is normally spread onto one acre of land for crops such as corn, soybean or wheat. Therefore, there will be considerable truck volume over the course of several weeks for large sites of several hundred acres. Increased traffic on local roads, odors and dust are potential impacts on the local community that should be addressed by notifying neighbors in public informational meetings or public hearings. Working out delivery schedules that are least likely to be disruptive will minimize the problems caused by biosolids transportation.



Tractor trailer delivering dewatered biosolids to an application site.

### Human health and environmental risks

#### Risk assessment approach to regulation

Quality standards and limits for pollutants in biosolids were developed from extensive environmental risk assessments conducted by scientists at the U.S. EPA and the U.S. Department of Agriculture. EPA used a rigorously reviewed methodology that they developed specifically for conducting the assessment (National Academy of Sciences, 1983; U.S. EPA, 1986). The goal of the risk assessment was to protect a person, animal or plant that is highly and continuously exposed to pollutants in biosolids. The rationale for this goal is that the general population would be protected if the regulations were developed to protect highly



exposed individuals.

The risk assessment process was the most comprehensive analysis of its kind ever undertaken by the EPA. The approach has since been applied to other materials, such as municipal solid waste compost. The resultant Part 503 Rule was designed to provide “reasonable worst-case,” not absolute, protection to human health and the environment.

### Part 503 risk assessment

The initial task of the 10-year risk assessment process was to establish a range of concentrations for trace elements and organic compounds that had the greatest potential for harm based on known human, animal and plant toxicities. Maximum safe accumulations for the chemical constituents in soil were established from the most limiting of 14 pathways of exposure (Table 4.1), which included risks posed to human health, plant toxicity and uptake, effects on livestock or wildlife, and water quality impacts. A total of 200 chemical constituents were screened by EPA, and 50 of these were selected for further evaluation, using the criteria above and the availability of data for

a preliminary risk assessment. Twenty-three of the 50 constituents were identified as warranting consideration for regulation based on the risk assessment. No regulatory limits were set for the 13 trace organic compounds in this group because the EPA risk assessment showed that the safe levels were much higher than the observed concentrations in biosolids. The 503 rule was then limited to ten trace elements (arsenic, cadmium, chromium, copper, lead mercury, molybdenum, nickel, selenium, and zinc). Chromium was subsequently dropped on a court challenge because the risk assessment had shown a very low risk level for this metal.

The most limiting pathway for each of the nine regulated trace elements was used to develop pollutant concentration limits and lifetime loading rate standards. For example, the greatest risk to a target organism from lead (Pb) is a child directly ingesting biosolids that have been applied to soil. The pollutant limits are therefore based on estimates of childhood soil consumption that EPA considered conservative (i.e., they predict a greater impact on human health than is likely to occur). Ingestion of biosolids is the

**Table 4.1**  
Exposure Pathways Used in the Part 503 Risk Assessment.

Pathway	Description of Highly Exposed Individual
1. Sludge→Soil→Plant→Human	Human (except home gardener) lifetime ingestion of plants grown in sludge-amended soil
2. Sludge→Soil→Plant→Human	Human (home gardener) lifetime ingestion of plants grown in sludge-amended soil
3. Sludge→Human	Human (child) ingesting sludge
4. Sludge→Soil→Plant→Animal→Human	Human lifetime ingestion of animal products (animals raised on forage grown on sludge-amended soil)
5. Sludge→Soil→Animal→Human	Human lifetime ingestion of animal products (animals ingest sludge directly)
6. Sludge→Soil→Plant→Animal	Animal lifetime ingestion of plants grown on sludge-amended soil
7. Sludge→Soil→Animal	Animal lifetime ingestion of sludge
8. Sludge→Soil→Plant	Plant toxicity due to taking up sludge pollutants when grown in sludge-amended soils
9. Sludge→Soil→Organism	Soil organism ingesting sludge-soil mixture
10. Sludge→Soil→Predator	Predator of soil organisms that have been exposed to sludge-amended soils
11. Sludge→Soil→Airborne dust→Human	Adult human lifetime inhalation of particles (dust) [e.g., tractor driver tilling a field]
12. Sludge→Soil→Surface water→Human	Human lifetime drinking surface water and ingesting fish containing pollutants in sludge
13. Sludge→Soil→Air→Human	Human lifetime inhalation of pollutants in sludge that volatilize to air
14. Sludge→Soil→Groundwater→Human	Human lifetime drinking well water containing pollutants from sludge that leach from soil to groundwater



most limiting pathway for five of the trace elements (As, Cd, Pb, Hg, and Se), phytotoxicity was most limiting for three trace elements (Cu, Ni, and Zn), and feed consumption by animal was the most limiting for Mo.

Under Part 503, the cumulative loading limits established by EPA for eight trace elements would allow the concentrations of these elements to increase to levels that are 10 to 100 times the normal background concentrations in soil (see Table 4.2). The time that it would take for each of the eight elements to reach its cumulative loading limit when biosolids with trace element concentrations equal to the means found in the National Sewage Sludge Survey (Table 3.1, U.S. EPA, 1990) are applied annually at a rate of 5 dry tons per acre is presented in Table 4.2. These are conservative estimates for Virginia, where agronomic loading rates are normally applied once every three years, not annually. The cumulative loading limits were developed to ensure that soil metals never reach harmful levels. Future applications of biosolids to the site would be prohibited if the cumulative loading limit for any of the eight trace elements was reached.

## Alternative regulatory approaches

### Best available technology

An alternative to the risk assessment approach,

termed “best available technology” or BAT, limits contaminants in biosolids to concentrations attained by the best current technology (e.g., industrial pre-treatment and separation of sanitary, storm and industrial sewerage). BAT is more restrictive of land application than risk assessment (i.e., lower pollutant concentrations can be attained using the best available technology than are permitted under the risk assessment approach). Biosolids are more likely to be landfilled or incinerated under this approach than under risk assessment.

### Non-contamination approach

The EPA Part 503 regulations take the position that all biosolids management options incur some risk, and that these risks can be evaluated so that regulations governing use and management options can be developed to reduce risk to acceptable (safe) levels. There are some who believe that the application of any biosolid that would cause an increase in the soil concentration of any pollutant is unacceptable. This is called the “non-contamination” approach. According to this approach, any addition of a pollutant to the soil must be matched by removal of that pollutant so that no long-term buildup occurs in the soil. This is the most restrictive of approaches to the land application of biosolids and is favored by those who believe that any increase in pollutant concentration in the soil is

**Table 4.2**

Possible trace element concentrations in typical unamended and biosolids-amended soils, and the time required to reach cumulative loading limits for the regulated trace elements.

Trace element	Typical background soil concentration range for non-contaminated <sup>a</sup>	Theoretical soil concentration at EPA cumulative loading limit <sup>b</sup>	Time required to reach cumulative loading limit <sup>c</sup>
	ppm	ppm	years
Arsenic	6-10	21	360
Cadmium	0.2-0.5	20	500
Copper	17-65	750	181
Lead	8-22	150	201
Mercury	0.06-0.15	9	320
Nickel	7-45	210	871
Selenium	0.3-0.4	50	1780
Zinc	19-82	1,400	208

<sup>a</sup> Penn State University, 1998

<sup>b</sup> Theoretical maximum soil concentrations after application of the maximum allowable amount of that element.

<sup>c</sup> Assumes an annual application rate of 5 dry tons/acre of a biosolid with trace element concentrations equal to the means in Table 3.1



undesirable, regardless of what risk assessment demonstrates. Although this approach reduces to zero any environmental risks from land application of biosolids, it diverts more biosolids to landfills or incinerators, thereby increasing the environmental risks associated with disposal and reduces recycling of nutrients and organic matter.

Each approach for regulating contaminants in biosolids has its technical and scientific foundation, but the approach selected is based primarily on legislative mandates and policy decisions.

### **Pathogen regulation**

Standards for pathogen reduction in biosolids were based on "best available technology." The EPA believes that the potential for pathogen transfer is negligible when biosolids are properly processed and the regulatory requirements for land application are met (U.S. EPA, 1987). The 503 rule establishes two levels of pathogen destruction - Class B, in which about 99% of the bacteria, 90% of the viruses, and a lower percentage of the more resistant parasites are killed; and Class A, where essentially 100% of all pathogens are destroyed. Protection against residual pathogens in Class B biosolids is achieved through crop harvesting restrictions, grazing restrictions, and public access restrictions based on the understanding that, given enough time, the residual pathogens in Class B biosolids are destroyed in the soil. Exposure to sunlight and temperature and moisture fluctuations in the soil reduces and eventually eliminates any viable pathogens that may remain in the biosolids (U.S. EPA, 1992c).

A positive trend relative to pathogen risk is that many Class B treatment processes are achieving near Class A pathogen levels. The trend was only identified because 503, for the first time requires pathogen testing for compliance. Another positive trend observed in recent years is the rapid increase in production of Class A biosolids, whose application to land poses essentially zero risk of pathogen transfer.

### **Can biosolids be used safely?**

Despite the endorsement of agricultural land application of biosolids by the U.S. EPA and a considerable number of agricultural and environmental scientists (National Research Council, 1996; American Society of Agronomy, 1994; Stukenberg et al., 1993), some scientists dispute the claim that biosolids used according to EPA guidelines can be safely applied in all instances. These scientists cite concerns about the buildup of toxic concentrations of trace elements in the soil and the food chain; the potential transport of pathogens into water, air and the human food chain;

the potential toxicity and carcinogenicity of the multitude of organic compounds; and risk from other constituents which have not been thoroughly studied (e.g., radioactive isotopes). They point to recommendations more conservative than 503 developed by the Technical Committee of Northeastern Regional Research Coordinating Project (NEC-28, Soil Research) [Pennsylvania State University, 1985] and the Cornell Waste Management Institute (Harrison et al., 1997). The NEC-28 recommendations contain much "best professional judgement," and call for reevaluation of the recommendations as research generates new knowledge.

### **Future Directions**

A second round of risk assessments will be conducted by the EPA. Several trace elements and organic chemicals that were not considered extensively during the initial risk assessments will be evaluated, and will include the results of numerous scientific studies completed since 1993. These activities will probably result in some changes of the current regulations. These changes could include (1) adding some organic chemicals (i.e., dioxins and co-planar PCBs) to the list of regulated pollutants and (2) adding a cumulative loading rate for molybdenum.

### **Conclusions**

Based on more than 25 years of research on land application of biosolids and an even longer record of beneficial use in the United States, the preponderance of scientific evidence indicates that land applying biosolids according to the regulations established by the U.S. EPA and the Commonwealth of Virginia will not result in significant detrimental health or environmental impacts. On-going research and evaluation of regulatory programs should continue until lingering arguments and concerns are satisfactorily addressed, or the questions raised will continue to create doubt among the public. Site specific assessment of the practice should take into account the potential for a specific biosolid to deviate greatly from the norm.



# Chapter 5

## Applying and Managing Biosolids on Agricultural Land

The general approach for determining biosolid application rates on agricultural land can be summarized as follows:

- 1) Determine nutrient needs for expected crop yield and soil test levels.
- 2) Calculate biosolids agronomic rates based on crop nitrogen (N) needs, soil test P needs, or soil lime requirement.
- 3) Calculate supplemental fertilizer needs by subtracting the amount of plant-available N, phosphorus (P), and potassium (K) supplied by biosolids from the crop N, P, and K needs.

### Determining nutrient needs

Fertilizer recommendations are based on the nutrients needed by crops to achieve their potential yield and the ability of the soil to provide the recommended nutrients. The amounts of N, P, and K required by most crops to achieve long term economically feasible and environmentally sound yields for soils in Virginia have been established experimentally and are published in the Virginia Agronomic Land Use Evaluation

System (VALUES; Simpson et al., 1993).

Soil testing is required prior to the application of biosolids to determine the suitability of soil pH and the availability of P and K. Soil testing can disclose whether limestone, P or K is required, either from the biosolids or as a supplement to the application. Nitrogen application rates are based on crop N needs for optimum yields for a specific soil.

### Determining agronomic rates

Regulations require that bulk biosolids be applied at a rate that is equal to or less than the agronomic N rate for the specific crop and soil type. Biosolids are normally applied at rates to supply the nitrogen needed by the crop ("agronomic N rate"). The relative concentrations of nutrients in biosolids are rarely present in the proportions required by the target crop; thus, supplemental fertilization may be needed to promote optimum vegetative growth and yield.

The type of information presented in Table 5.1, which is adapted from VALUES, is used to estimate the amount of N that can be used by various crops

**Table 5.1**

Historical mean yields and potential biosolid N utilization of various crops grown on soils of different productivity groups (Excerpted from Virginia Biosolids Use Regulations - Table 11).

Crop	Soil Productivity Group IIA		Soil Productivity Group IIIB	
	Mean yield	N use lb/ac	Mean yield	N use lb/ac
Corn				
grain (yield=bu/ac)	140	140-160	110	110-130
silage (yield=tons/ac)	19	140-160	16	110-130
Soybean (yield=bu/ac)				
early season	40	140-160	35	110-130
late season	34	140-160	25	110-130
Wheat (yield=bu/ac)				
standard	56	90	48	80
intensive	70	90	60	80
Tallgrass hay (yield=tons/ac)	3.5-4	250	< 3	200
Pasture - fescue/orchardgrass	<sup>a</sup>	120	<sup>a</sup>	100
Alfalfa (tons/ac)	4-6	300	< 4	210

<sup>a</sup> Insufficient data to make a good estimate.



grown on biosolid-amended soils. Fertilizer N is not normally applied to legumes, which can obtain N from the atmosphere; however, nitrogen uptake has been used to establish agronomic N rates for legumes because they will use biosolids-furnished soil nitrogen.

### Why are biosolids' applications usually based on crop N needs?

Nitrogen is required by crops in greater amounts than any other nutrient; thus, the crop requirements for most other nutrients are normally met when the agronomic N rate is applied. In addition, N is the nutrient most likely to be lost to surface and ground water if applied at greater than agronomic rates.

Several cautions regarding the determination of agronomic N rates are in order. (1) The amount of plant-available N can be underestimated or overestimated because the N composition of biosolids that is used to establish the average N concentration can vary significantly during the period of time that samples are collected and analyzed to establish the agronomic N rate. (2) The equations used to calculate plant-available N are not site or source specific, and the actual amounts of plant-available N may vary from the target

rates. These problems occur with other types of organic wastes, such as manures and yard waste composts, and are not unique to biosolids.

### What is PAN and how is it determined?

Plant available nitrogen (PAN) is the actual amount of N in the biosolids that is available to crops during the season of application. Equations for calculating PAN are relatively simple; however, choosing reasonable input values is more challenging. "Suggested" values for all necessary parameters are provided in Tables 5.2 and 5.3, but site-specific data, when available, should always be used in preference to "typical" values.

### How are the availabilities of the different forms of N in biosolids determined?

Nitrogen in biosolids may be found in the ammonium (NH<sub>4</sub>) or nitrate (NO<sub>3</sub>) forms found in commercial inorganic fertilizers, or in organic forms found in manures and composts. The form of nitrogen determines how much nitrogen will be available to plants. Nitrate is readily plant available but is not found in high concentrations in most biosolids. Ammonium is

**Table 5.2**

Estimated plant-available percentage of ammonia from biosolids (adapted from Virginia BURs - Table 12).

Management practice	Available portion (%)	
	Biosolids pH<10	Biosolids pH>10
Injection below surface	100	100
Surface application with/		
— Incorporation within 24 hours	85	75
— Incorporation within 1-7 days	70	50
— Incorporation after 7 days	50	25

**Table 5.3**

Estimated percentage of organic N that becomes available for plant uptake at various times after application for different biosolids (adapted from Virginia BURs - Table 12).

Time after application	Lime stabilized	Aerobically digested	Anaerobically digested	Composted
Years	Plant available portion of organic N (%)			
0-1	30	30	20	10
1-2	15	15	10	5
2-3	7	8	5	3



also available to plants, but it can be lost to the atmosphere (volatilization) as ammonia ( $\text{NH}_3$ ) gas and when biosolids are applied to land without prompt incorporation into the soil. The available (non-volatilizable) fraction of  $\text{NH}_4\text{-N}$  may be estimated from the values in Table 5.2.

Organic nitrogen must be broken down to  $\text{NH}_4^+$  and  $\text{NO}_3^-$  (mineralization) by soil microorganisms before this form of nitrogen is available for plants to use; therefore, organic nitrogen can be considered to be a slow release form of nitrogen. The amount of PAN from organic nitrogen is estimated by using factors established by research, such as those presented in Table 5.3. The largest portion of organic nitrogen in biosolids is converted to plant available N during the first year after application to the soil.

As an example, the amounts of organic N that will become available for plant uptake upon mineralization of an aerobically digested biosolid (Table 5.3) are: 30% during the first year after application, 15% of the remaining organic N during the second year, and 8% of the remaining organic N during the third year. No additional credit for residual N is calculated after year 3 because the amounts are so small. The values in Table 5.3 may not be the most appropriate for all biosolids applied to any soil, but they are normally used when site specific data are not available. The amounts of available ammonium ( $\text{NH}_4$ ) plus the available portion of the organic N (from Table 5.2) are used to calculate the rate of biosolids needed to supply a given amount of plant available N.

#### **Will agronomic N rates of biosolids meet crop needs of all nutrients?**

Not necessarily. Potassium (K) is often recommended for agronomic crops grown in Virginia soils, but the nutrient is present in low concentrations in biosolids. Supplemental potassium fertilization based on soil testing may be required for optimum plant growth where biosolids are applied. Research is currently being conducted to alkaline stabilize biosolids with caustic potash. This could increase the value of biosolids by fortifying the material with potassium.

Magnesium deficiencies have been reported in row crops where repeated application of calcium carbonate limestone has reduced soil magnesium concentrations. Such soils can be identified by soil testing and should not receive further additions of "calcium only" liming materials, such as lime-stabilized biosolids.

#### **How are the plant availabilities of P and K from biosolids determined?**

EPA estimates that 50% of the P and 100% of the K applied in biosolids are available for plant uptake in

the year of application. These quantities can be credited against fertilizer recommendations. Any P and K in excess of plant needs will contribute to soil fertility levels that can regularly be monitored via soil testing and taken into account when determining fertilizer recommendations in succeeding years.

#### **What problems may be caused by applying biosolids at agronomic N rates?**

Biosolids normally supply similar amounts of plant available nitrogen and phosphorus, but crops require one-fifth to one-half as much phosphorus as nitrogen. The extra phosphorus accumulates in the soil, where high concentrations may increase phosphorus runoff into surface water. Phosphorus enrichment of surface water can cause algal blooms that subsequently deplete oxygen for plant and animal life. The potential for such contamination exists where biosolids are repeatedly applied at agronomic N rates. Applying biosolids at rates to supply the phosphorus needs of the crop, where soil P levels are already high, can alleviate the potential of phosphorus runoff. In this case, the farmer would probably have to purchase nitrogen to meet the crop needs.

#### **Can the proper biosolids application rate be determined by other fertility parameters?**

The pH of sandy soils can rise rapidly when limed. Deficiencies of manganese in wheat and soybean and zinc in corn have sometimes been caused by excessive liming ( $\text{pH} > 6.8$ ) of these soils, which are largely found in the Virginia Coastal Plain (east of I-95). Application of lime-stabilized biosolids at agronomic N rates onto sandy soils that already have high pHs can induce such deficiencies. Crop yield reductions can result if the deficiency is not corrected, and the soil nitrogen not utilized by the crop can potentially leach into groundwater. Thus, soil pH should be maintained within the recommended range (5.8-6.5) for soils and crops.

Soil pH influences the availability and toxicity of naturally occurring metals and metals applied to soil in biosolids. Most crops grow well in Virginia soils at pH levels between 5.8 and 6.5. Based on previous EPA guidance, some states require that soils treated with biosolids be maintained at a pH of 6.5 or above to reduce metal uptake by crops. Federal and state regulations do not require a minimum soil pH because pH was factored into the Part 503 risk assessment on which the regulation was based (U.S. EPA, 1992b). It is advisable to maintain the pH of agricultural soils where biosolids have been applied in the optimum range for crop growth (i.e., 5.8 to 6.5) to avoid toxicity of background or biosolids-supplemented metals.



## Determining supplemental fertilizer needs

The amounts of plant-available nitrogen, phosphorus, and potassium, and other nutrients added by the biosolid should be calculated once the application rate has been determined. Supplemental fertilizers should be applied if the amount of any nutrients in the biosolid is less than that recommended.

## Selection of suitable crops for fertilization with biosolids

High N-use crops such as corn, soybean, small grains, and forages will minimize the amount of land needed for biosolid application and will benefit from the N supplying capability of biosolids. Crops grown for their flowering parts, such as cotton, can produce undesirable amounts of vegetative growth if they continue to accumulate N late in the season. Slow release N sources such as biosolids and manures may impair the quality of such crops; however, biosolids can be used efficiently on other crops in rotation with cotton.

Biosolids can be applied to vegetable crops, but green leafy vegetables tend to accumulate higher concentrations of metals than the grain of agronomic crops. Some scientists have cautioned against using biosolids on vegetable crops because they provide a direct conduit of potentially harmful trace elements from the soil to humans. Therefore, grain and forage crops are better choices for biosolids application than vegetables. Tobacco accumulates heavy metals such as Cd in high concentrations, and the use of biosolids on tobacco ground is not recommended.



Corn fertilized with biosolids.

## Application methods

The most appropriate application method for agricultural land depends on the physical characteristics of the biosolids and the soil, as well as the types of crops grown. Biosolids are generally land applied using one of the following methods: 1) sprayed or spread on the soil surface and left on the surface for pastures, range and forest land; and 2) incorporated into the soil after being surface applied or injected directly below the surface for producing row crops or other vegetation. Both liquid and dewatered biosolids may be applied to land with or without subsequent soil incorporation.

Liquid biosolids can be applied by surface spreading or subsurface injection. Surface methods include spreading by tractor drawn tank wagons, special applicator vehicles equipped with flotation tires, or irrigation systems. Surface application with incorporation is normally limited to soils with less than a 7 percent slope. Biosolids are commonly incorporated by plowing or discing after the liquid has been applied to the soil surface and allowed to partially dry, unless minimum or no-till systems are being used.

Spray irrigation systems generally should not be used to apply biosolids to forages or row crops during the growing season, although a light application to the stubble of a forage crop following a harvest is acceptable. The adherence of biosolids to plant vegetation can have a detrimental effect on crop yields by reducing photosynthesis. In addition, spray irrigation increases the potential for odor problems and reduces the aesthetics at the application site.

Liquid biosolids can also be injected below the soil surface using tractor-drawn tank wagons with injection shanks and tank trucks fitted with flotation tires and injection shanks. Both types of equipment minimize odor problems and reduce ammonia volatilization by



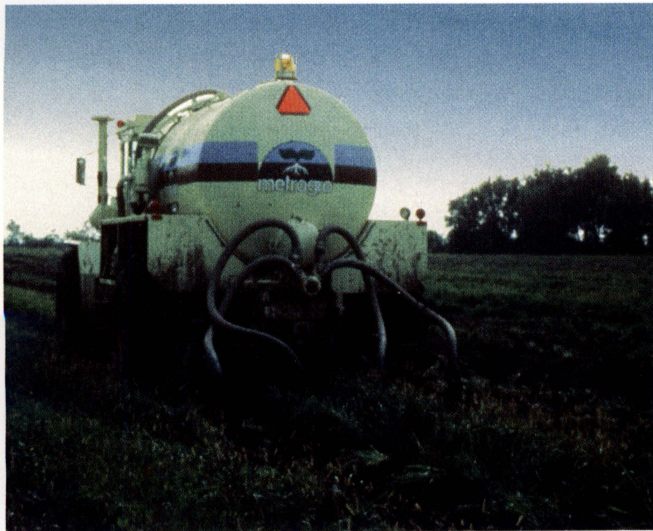
Liquid biosolids being applied to the surface of a pasture.



immediate mixing of soil and biosolids. Injection can be used either before planting or after harvesting crops, but it is likely to be unacceptable for forages and sod production. Some injection shanks can damage the sod or forage stand and leave deep injection furrows in the field. Equipment with specialized injection shanks has been developed that will not damage the growth of forage and sod crops.

Subsurface injection will minimize runoff from all soils and can be used on slopes up to 15 percent. Injection should be made perpendicular to slopes to avoid having liquid biosolids run downhill along injection slits and pond at the bottom of the slopes. As with surface application, the drier the soil the more liquid it will be able to absorb, thereby minimizing downslope movement.

Dewatered biosolids can be applied to cropland by equipment similar to that used for applying limestone,



Liquid biosolids being injected into a vegetative cover.



Spreading of dewatered "cake" biosolids from a manure-type spreader in preparation for planting corn

animal manures or commercial fertilizer. Typically, dewatered biosolids will be surface-applied and incorporated by plowing or another form of tillage. Incorporation is not used when applying dewatered biosolids to forages. Biosolids application methods such as incorporation and injection can be used to meet Part 503 vector attraction reduction requirements.

## Timing of biosolids application

The timing of biosolid land applications must be scheduled around the tillage, planting and harvesting operations and will be influenced by crop, climate, and soil properties. Traffic on wet soils during or immediately following heavy rainfalls may cause compaction and leave ruts in the soil, making crop production difficult and reducing crop yields. Muddy soils also make vehicle operation difficult and can create public nuisances by carrying mud out of the field and onto roadways.

Applications should also be made when crops will soon be able to utilize the N contained in the biosolids. Failure to do so could result in potential nitrate contamination of groundwater due to leaching of this water-soluble form of nitrogen. Biosolids that are applied to land between autumn and spring should have a vegetative cover (i.e., permanent pasture, winter cover crop, winter annual grain crop) to reduce erosion of sediment-bound biosolids, runoff of N, P and pathogens, and leaching of nitrate.

Split applications may be required for rates of liquid biosolids (depending on the solids content) in excess of 2-3 dry tons/acre. Split application involves more than one application, each at a relatively low rate, to attain a higher total rate when the soil cannot assimilate the volume of the higher rate at one time.

## Biosolids storage

Storage facilities are required to hold biosolids during periods of inclement weather, equipment breakdown, frozen or snow-covered ground, or when land is unavailable due to growth of a crop. Liquid biosolids can be stored in digesters, tanks, lagoons, or drying beds; and dewatered biosolids can be stockpiled. The BURs specify that biosolids stored for more than 30 days must be placed into a specially designed, permitted, storage facility.



### Who can provide information about the permitting process for land application?

Guidelines for obtaining approval for land application of biosolids are available from field offices of the State Department of Health, Office of Environmental Health Services.

### What are the normal steps for approval of land application of biosolids in a Virginia county?

- 1) Contractor proposes land application to landowner and farmer(s), secures agreement, and submits a complete, site specific permit application to the Virginia Department of Health (VDH). The VDH notifies the local government of the permit application and requests comment.
- 2) When the application is for a new permit for sites in a county, a public informational meeting is held at which agronomic, health and environment, regulatory, and logistical land application issues are addressed by representatives of the VDH, the biosolids' contracting company, and, often, Virginia Tech and/or Virginia Cooperative Extension (VCE). Speakers representing other state agencies that participate in the biosolids use program (i.e., Virginia Department of Conservation and Recreation [VDNR], and Virginia Department of Environmental Quality [VDEQ]) sometimes make presentations at these meetings.
- 3) Biosolids contractor addresses comments concerning the permit application with the local government and VDH. The following steps may be included in the permit review process to further address specific controversial issues:
  - a) County public hearing before the Board of Supervisors may be held. VDH, Virginia Tech/VCE, the biosolids contractor and (sometimes) VDNR and VDEQ are represented at these meetings to provide information to the Board to assist them in making decisions regarding biosolids use in their county. The county has the option to permit land application according to VDH state regulations, deny land application outright, or permit land application with additional local regulations (ordinances). The state permit will be issued in cases where the contractor is in compliance with the existing special use ordinance.

- b) If the county does not deny the permit but includes additional ordinance items, the contractor agrees to or declines the offer to apply biosolids according to the provisions stated in the ordinance.

- 5) The VDH approves or rejects the permit application following the public meeting or receipt of local government and other agency comments. The existing permit may be modified during this process.
- 6) The biosolids contractor begins the land application program according to the permit requirements, regulations and ordinances.

### Who is responsible for collecting information, obtaining approval, and properly applying the material?

Usually, sewage treatment plant personnel or biosolids application contractors.

### Who is responsible for recordkeeping and reporting?

Persons who prepare biosolids for land application must provide information necessary to demonstrate compliance with the state and federal regulations to the land appliers. The persons who apply the biosolids to the land are responsible for obtaining from the preparer information necessary to demonstrate compliance with the rule.

### Who assumes liability for improper management of biosolids?

The generator of the biosolids is liable for the material if its utilization results in a health or environmental problem. The Part 503 Rule requires that the treatment works will be held accountable if it uses a contractual applier who does not change the quality of the biosolids for land application since the EPA considers that the treatment works still retains control over the quality of the material. Therefore, municipalities may wish to monitor contract haulers and/or land appliers carefully. Conversely, the contractor should not be placed into a contractual responsibility for land applying biosolids that are not acceptable to nearby residents.



**How can good biosolids management be ensured?**

Regulatory officials have the authority to inspect operations, review records, sample applied biosolids, and generally respond to complaints concerning public health or public nuisances. EPA may pursue enforcement actions when necessary to address violations, whether willful or the result of negligence. Private citizens may pursue civil remedies against a violator under the Clean Water Act in the absence of a government enforcement action.



# References

---

- American Society of Agronomy. 1994. Sewage sludge: Land utilization and the environment. C.E. Clapp, W.E. Larson, and R.H. Dowdy (eds.) SSSA Miscellaneous Publication. 257 p.
- Harrison, E.Z., M.B. McBride, and D.R. Bouldin. 1997. The case for caution: Recommendations for land application of sewage sludges and an appraisal of the U.S. EPA's Part 503 sludge rules. Cornell Waste Management Institute. Cornell University, Ithaca, NY.
- National Academy of Sciences. 1983. Risk assessment and management: Framework for decision-making. Washington, DC.
- National Research Council. 1996. Use of reclaimed water and sludge in food crop production. National Academy Press, Washington, D.C.
- Pennsylvania State University. 1985. Criteria and recommendations for land application of sludges in the northeast. Technical Committee of Northeastern Regional Research Coordinating Project NEC-28, Soil research. Northeastern Regional Research Publication. 94 p.
- Pennsylvania State University. 1998. Land application of sewage sludge in Pennsylvania: What is sewage sludge and what can be done with it? Pennsylvania Cooperative Extension Publication. 7 p.
- Shimp, G., K. Hunt, S. McMillian, and G. Hunter. 1994. Pretreatment raises biosolids quality. *Environ. Protection* 5(6).
- Simpson, T.W., S.J. Donohue, G.W. Hawkins, M.M. Monnett, and J.C. Baker. 1993. The development and implementation of the Virginia Agronomic Land Use Evaluation System (VALUES). Department of Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg, VA. 83 p.
- Sommers, L. 1977. Chemical composition of sewage sludges and analysis of their potential use as fertilizers. *J. Environ. Qual.* 6:225-239.
- Stukenberg, J.R., S. Carr, L.W. Jacobs, and S. Bohm. 1993. Document long-term experience of biosolids land application programs. WERF Project 91-ISP-4. Water Environment Research Foundation, Alexandria, VA. 216 p.
- U.S. EPA. 1995. Process Design Manual: Land Application of Sewage Sludge and Domestic Septage, Office of Research and Development. EPA/625/R-95/001. Washington, D.C.
- U.S. EPA. 1993. Standards for the use or disposal of sewage sludge; final rules. 40 CFR Parts 257, 403 and 503. Pp. 9248-9415. U.S. Government Printing Office, Washington, D.C.
- U.S. EPA. 1992a. Technical support document for land application of sewage sludge, Vol. I. EPA/822/R-93900/9. Washington, D.C.: U.S. Environmental Protection Agency.
- U.S. EPA. 1992b. Technical support document for land application of sewage sludge, Vol. I. EPA/822/R-93/001A. Washington, D.C.: U.S. Environmental Protection Agency.
- U.S. EPA. 1992c. Technical support document for reduction of pathogens and vector attraction in sewage sludge. EPA R-93-004. Washington, D.C.: U.S. Environmental Protection Agency.
- U.S. EPA. 1990. National sewage sludge survey: Availability of information and data, and anticipated impacts on proposed regulations. *Fed. Reg.* 55(218).
- U.S. EPA. 1987. Survival and transport of pathogens in sludge-amended soil: A critical review. EPA/600/2-87/028. Cincinnati, OH.
- U.S. EPA. 1986. Guidelines for carcinogen assessment; Guidelines for estimating exposure; Guidelines for mutagenicity risk assessment; Guidelines for health assessment of suspect developmental toxicants; and Guidelines for health risk assessment of chemical mixtures. *FR Vol. 51, No. 185.*
- U.S. EPA. 1984. Use and disposal of municipal wastewater sludge. EPA/625/10-84/003. Cincinnati, OH.
- Virginia Department of Health. 1997. Biosolids Use Regulations. 12 VAC 5-585-10 et seq. 32.1-164.5 of the Code of Virginia.





1999

PUBLICATION 452-300

Virginia Cooperative Extension programs and employment are open to all, regardless of race, color, religion, sex, age, veteran status, national origin, disability, or political affiliation. An equal opportunity/affirmative action employer. Issued in furtherance of Cooperative Extension work, Virginia Polytechnic Institute and State University, Virginia State University, and the U.S. Department of Agriculture cooperating. J. David Barrett, Interim Director, Virginia Cooperative Extension, Virginia Tech, Blacksburg; Lorenza W. Lyons, Administrator, 1890 Extension Program, Virginia State, Petersburg.

VT/028/0599/1M/993929/452300

Background photo courtesy of Nutri-Blend, Inc.