Applying Biosolids: Issues for Virginia Agriculture

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TABLE OF CONTENTS

INTRODUCTION

Each year the United States generates 5.3 million metric tons, dry weight, of sewage sludge (sludge) from waste water treatment. Communities must dispose of this sludge. According to the United States Environmental Protection Agency (EPA), 36 percent is applied to agricultural land, turfgrass, and mining reclamation land; 38 percent is put in landfills; 16 percent is incinerated; and 10 percent is disposed of in other ways (EPA p. 2). EPA uses the term "biosolids" to distinguish the sludge applied on agricultural land from raw sludge and sludge high in pollutants. "Biosolids are solid, semisolid or liquid materials, resulting from treatment of domestic sewage, that have been sufficiently processed to permit these materials to be safely land-applied" (Evanylo, 1997, p 2).

Public health and environmental concerns about biosolids focus on heavy metals, volatile organic compounds, and pathogens, all of which can cause health and environmental damage. Consequently, the Virginia Department of Health administers and monitors the permitting and land application of biosolids in Virginia to prevent negative human health impacts and minimize environmental risk.

On January 12, 2001, the State Supreme Court of Virginia struck down an April 1999, Amelia County ordinance that banned applications of biosolids. The decision determined that local governments cannot prevent the application of biosolids on agricultural lands when the application is properly permitted by the state. The Virginia Supreme Court decision reaffirms the existing legal authority of the state to permit biosolids applications and supports the existing permitting process. The State Supreme Court decision infers that the existing scientific understanding and regulatory framework for agricultural applications of biosolids are acceptable.

In addition, Governor Gilmore signed legislation (HB 2827)[1] allowing local governments to charge fees to biosolids contractors. These fees are to cover the cost of more careful local monitoring and testing of biosolids applications. The fees cannot exceed the cost of the monitoring and testing. The law requires the state Department of Health to adopt a fee schedule by July 1, 2002 for local government implementation. The General Assembly's new legislation acknowledges that local acceptance of biosolids applications is still a political issue in many localities and, therefore, grants localities the ability to generate funds for local oversight. What this added level of local monitoring and testing will add to the scientific knowledge underpinning the agricultural use of biosolids and how it will impact application rates are yet to be determined.

In Virginia, approximately 30,000 acres of farmland are permitted for the application of biosolids each year (Evanylo and Ross, 1997). In 1998, 61 percent of all biosolids applied were applied in northern and central Virginia, and 15.5 percent were applied in eastern Virginia (Table 1).

Biosolids are a low analysis nutrient source for both micro and secondary nutrients. However, their use can provide soil, yield, and economic benefits. To maximize the use of biosolids while minimizing the associated risks, farmers and biosolids providers need to consider the following broad areas:

- soils,
- biosolids,
- production practices,

[1] House Bill No. 2827 signed by Governor Gilmore April 9,2001, Acts of Assembly Chapter text (CHAP0831). The text can be found at *http://leg1.state.va.us/cgi-bin/legp504.exe?011+ful+HB2827H1*. Accessed March 30, 2001

- economics,
- environmental impacts, and
- nuisances.

Prudent consideration of these areas is needed for biosolids applications to be most useful in reducing costs to everyone (tax payers through their municipal waste water treatment plants, biosolids suppliers, and farmers). Suppliers must know the regulations governing the use of biosolids and pay careful attention to the details of each application to safeguard human health and the environment. Productive and environmentally beneficial use of biosolids requires that farmers know their soils and the nutrient requirements of the crops they grow. Agricultural application makes productive use of biosolids and is less costly to society than disposing of them in landfills or through incineration.

Table 1. Land Application of Municipal Biosolids in Virginia

District[1]	Acres	Percent of biosolids
Central	7,830	28.3
Eastern	4,285	15.5
Northern	9,054	32.7
Southern	2,237	8.1
Southeastern	370	1.3
Western	484	1.8
Southwestern	0	0.0
Other	3,398	12.3
Total	**27,658**	**100.0**

[1] Districts correspond to Virginia Agricultural Statistic Service Crop Reporting Districts with the exception of "Other." Other includes data for individual counties that cannot be identified from the original data because of disclosure problems.
Source: Virginia Department of Health

SOILS

The additional organic matter content from biosolids increases the water holding capacity of the soil. Such increases in organic matter content are small, but organic matter is so important for soil quality that even small amounts sometimes make a difference. For example, sufficient amounts of organic matter may be added through biosolids applications for some soils to have the ability to mitigate the effects of dry periods during critical growth stages.

Increased organic matter improves soil structure, water infiltration, and water holding capacity. Soil structure improves because the organic matter causes soil particles to bond together to form loose soil aggregates. The formation of soil aggregates results in the creation of spaces in the soil. These spaces allow for more free movement of gases in the soil as well as for more rapid water infiltration. The combination of soil particle looseness (friability) and space-creating aggregates encourages the creation of a healthier microenvironment in the soil. As soil quality improves, conditions in the soil profile become more conducive to the propagation of beneficial worms, predatory insects and spiders, and microorganisms which further contribute to soil quality. These same features that characterize soil quality and enhance productivity also decrease surface runoff during and after rainfall, decrease on-site soil erosion and sediment delivery to receiving water courses and water bodies, and decrease non-point source pollutants delivered to waterways in general.

The value of biosolids and the potential for environmental damage from surface runoff and subsurface leaching varies by the mineralization rate for the site and the characteristics of the biosolids. Mineralization rates, or the rate at which nitrogen (N) tied-up in organic matter becomes available to plants in ammonium (NH_4) and nitrate forms (NO_3), varies with the source as well as site-specific characteristics such as temperature, rainfall, elevation, slope, aspect, latitude, and ground cover. Mineralization rates are generally greater in the coastal plains than in the Piedmont or mountains and valleys because of the warmer, wetter climate. Lime stabilized and aerobically digested biosolids have mineralization rates that are faster than anaerobically digested biosolids (Table 2). Other nutrients, including phosphorous, potassium, and micronutrients, are also available in subsequent years to benefit later crops. In drought years, these residual nutrients are harder to estimate. But their benefit in the soil after a drought year is pronounced simply due to lowered crop uptake.

Table 2. Plant Available N after Biosolids Application

Years after application	Lime stabilized	Aerobically digested	Anaerobically digested	Composted
	----------------------------------	(%)	----------------------------------	
0-1	30	30	20	10
1-2	15	15	10	5
2-3	7	8	5	3

Source: Gregory Evanylo, *Land Application of Biosolids for Agricultural Purposes in Virginia*, VCE Pub. 452-300, 1999, p.18

BIOSOLIDS

The nutrient content and percent solids varies by type of biosolids (Table 3). To estimate the pounds of nutrients per ton of dry biosolids, the nutrient content percent is multiplied by 2,000 pounds. For example, lime-stabilized biosolids average around 3 percent total N, including both organic and inorganic forms; therefore, one ton will contain approximately 60 pounds total N (0.03 * 2,000 pounds = 60 pounds total nitrogen). Five to seven dry tons of dry biosolids are typically applied per acre of crop or pasture land in Virginia; therefore, approximately 360 pounds total N per acre are commonly applied through biosolids (0.03 * 2,000 pounds * 6 tons = 360 pounds total N). However, total N and plant available nitrogen (PAN) from biosolids are not the same. Most of the N contained in biosolids is organic, which is a slow release form. Thus, the PAN is a fraction of the total N contained in the material. The amount of PAN is a function of the NH_4 and NO_3 that are already available to the plant and the mineralization process. For lime-stabilized biosolids, the PAN during the first year after application is about 30 percent. In the 360 pounds total N applied example, approximately 108 pounds of organic N (360 pounds * 0.3 = 108 pounds PAN) would be mineralized into inorganic forms and be available for plant uptake during the first year after application.

Table 3. Average Nutrient Value for Typical Biosolids in Virginia on a Dry-Weight Basis

Type Biosolids	Nitrogen (N)	Phosphorous (P)	Potassium (K)
	-------------------------	%	----------------------------
Lime Stabilized	2.0-4.0	1.0-2.0	0.5
Non-Lime Stabilized	4.0-6.0	2.0-3.0	1.0
Composted	0.5-1.0	0.2-0.4	0.1
Heat-Dried and Pelletized	4.0-6.0	2.5-3.0	1.0

Source: D. Steven McMahon, Technical Services Administrator, Wheelabrator Water Technologies Inc., Bio Gro Division, personal communications, February 19, 1996.

Biosolids stabilized with lime (calcium hydroxide) can cause calcium/magnesium imbalances in the soil. These imbalances can lead to grass tetany (magnesium deficiency) in livestock, especially lactating cows. This imbalance is more likely to occur on sites with sandy soils that are already low in magnesium and have higher pH levels (6.2 or above). Therefore, lime-stabilized biosolids should not be applied on any soil with a pH greater than 6.2. The higher pH can also lead to a reduction in the availability of other nutrients such as manganese, iron, copper, and zinc because the solubility of these trace elements goes down as the pH goes up.

Recent changes to Virginia regulations prohibit the application of lime-stabilized biosolids on Coastal Plains soils with pH levels greater than 6.3 and on non-Coastal Plains soils with pH levels greater than 6.5. Thus, nutrients and lime content are both limiting factors that determine the quantity and type of biosolids that can be applied on a given site.

Biosolids are delivered in large dump trucks, usually with a 20-ton capacity. Delivery truck traffic at off-loading areas when the biosolids are dumped and windrowed can cause compaction, as can tractors being repeatedly loaded to spread the material. Occasionally, some of the off-loading areas in grass fields may need reseeding or cultivation to breakup compaction. Farmers report that approximately 5 to 10 percent of a given field is compacted. Compaction adds the cost of extra land preparation. Further, these off-loading areas tend to receive more biosolids and nutrients than the rest of the field. Farmers report that windrow areas suffer a yield decrease in the first season after application, but typically experience a yield enhancement the following season. Very little nutrient-laden water is actually lost under the windrowed piles in off-loading areas in spite of the high liquid content (typically 75 to 85 percent). The material does not readily lose water due to its high organic matter.

Poor coordination between the farmer and supplier can result in disruptions to production plans, operational conflicts, increased farm costs, and suboptimal use of the biosolids. The economic and environmental success of biosolids use depend on the competence and professionalism of the service providers and farmers' knowledge of their soils and crop requirements.

PRODUCTION CONSIDERATIONS

Because biosolids applications work better with some crops and in some crop rotations than others, farmers need to be sure that the applications will fit their crop rotations. Some crops, such as green leafy vegetables and tobacco, tend to accumulate higher concentrations of metals than grain crops. As a result, the application of biosolids on leafy vegetables and tobacco is not recommended.

The timing of biosolids application is very important. Applications made too early in the growing season could result in added weed competition. Late applications can interfere with seedbed preparation and planting. Poor coordination between the farmer and supplier can result in operational delays, poor use of farm labor, inconveniences, and failure to maximize plant growth and yield.

Biosolids applications generally work well on cropland in the Piedmont and Coastal Plains of Virginia if applied in the spring before planting corn or full-season soybeans or if applied in the fall after corn harvest and before planting small grains. Spring applications to corn and full-season soybeans provide the best results.

If the applicator supplies the double crop requirement for both small grain and the subsequent corn or soybeans crop in one fall application, N overloading of small grain crops can result in lodging. Lodging can also occur if the farmer over applies commercial fertilizer to add supplemental nutrients. This problem can be avoided by split applications of nutrients, by soil testing, by the quick nitrate test, and by tissue analysis of the standing crop.

Biosolids should be applied to forages and hay crops in the early spring (March-April) or late summer (August-September). Applications during these time periods make the nutrients available just before periods of maximum cool season grass nutrient uptake. Early spring and late summer applications also help minimize disruption of cool season forage growth from smothering effects. Summer applications, depending on weather conditions at the time, can result in some nutrient burning of hay or pasture because the drier conditions and higher temperatures have already stressed cool season grasses. Prior to application, pasture fields must be grazed to 4 inches and hay cut to 6 inches. No application may be made to warm season grasses and alfalfa between September 15 and March 15 because these species are not actively growing during this time and do not utilize nutrients.

Federal and state biosolids regulations forbid the grazing of beef cattle within 30 days of application and within 60 days for lactating dairy cows. Since most pathogens die from exposure to sunlight and changes in temperature, moisture, and soil conditions, these regulations are intended to help assure that grazing livestock have minimal exposure to pathogens contained in the biosolids. Therefore, any grazing operation receiving biosolids must either have sufficient additional acreage that does not receive biosolids or have sufficient hay or other feed to maintain herd condition until the waiting period has passed.

ECONOMICS

Biosolids are supplied free to the cooperating farmer. Because biosolids provide nutrients, the amount of commercial fertilizer applied can be reduced, resulting in a cost savings. The amount of that cost savings is dependent on the nutrient content of the biosolids. Case studies show the first year economic value of nutrients derived from biosolids in the Coastal Plains and Piedmont regions of Virginia range from $25 to $50 per acre on pasture land and $50 to $70 per acre on corn, small grains, and soybean land.[2] Additional savings, up to $12 per acre, can be realized when the biosolids supplier disks fields to incorporate the biosolids into the soil—assuming the timing of application and incorporation reduces the farmer's land preparation requirements.

If lime-stabilized biosolids are applied, farmers reduce the cost of lime application, which typically ranges from $9 to $18 per acre and can last up to three years. Soil structure is improved through the addition of organic matter contained in biosolids. Measuring the benefits and putting a dollar value on the micro- and secondary nutrients and soil structure improvement are very difficult. In many cases, these benefits accrue over a long period. No attempt was made to measure the residual nutrient value for subsequent crops.

Biosolids application regulations require that the supplier routinely soil test fields. Thus, for farmers who do not test as much or as frequently as is generally recommended, the soil test results associated with biosolids applications provide them with more information for management decisions than they would otherwise have available. In addition to the information, a minor cost savings accrues to the farmer.

2 These estimates were based on $0.23 per pound for N, $0.30 per pound for P, and $0.14 per pound for K. The quantities of biosolids and nutrient analysis information are based on case studies for the L. C. Davis farm in New Kent County, the J. R. Smith farm in Louisa County, and the J. B. Cocke farm in Hanover County.

Farmers typically pay about $7 to 10 per soil sample analyzed and take one soil sample for every 10 to 15 acres. Thus, a farmer could save approximately $0.70 to $1.00 per acre on every field where biosolids application is planned.

Three Case Studies

The Hanover-Caroline and Colonial Soil and Water Conservation Districts, as part of their 1997 York and Rappahannock River Tributary Strategies Project, selected three farms for case studies of biosolids application. Two farms are in the Piedmont Plateau (Hanover and Louisa counties), the third is in the Coastal Plains (New Kent County). The Louisa County farm is a grazing operation, and the Hanover and New Kent county farms are corn, small grain, and soybean operations. The results clearly indicate positive net economic benefits in each case.

Because yields, mineralization rates, leaching, and runoff are functions of soil type, slope, temperature, and rainfall, tables 4 and 5 are provided as references for the three case study farms.

Table 4. Soil Properties

Property	Cecil, 14C2	Appling, 3C2	Bojac, 5A	Pamunkey
Slope range (%)	7-15	7-15	0-2	0-2
Slope length (ft)	80-400	120-500	Nearly level	Nearly level
Erosion hazard	Severe	Severe	Slight	Slight
Permeability	Moderate	Moderate	Moderately rapid	Moderate
Available water capacity	Moderate	Moderate	Low	Moderate
Surface runoff	Medium to rapid	Medium to rapid	Low	Slow
Tilth	Fair	Fair	Good	Good
Organic matter	Low	Low	Low	Low
Natural fertility	Low	Low	Low	Medium
Subsoil	Predominantly clay	Predominantly clay	Fine sandy loam	Sandy clay loam and sandy loam
Root zone depth (inches)	60	60	70-85	> 60

Table 5. Average Daily Temperature and Average Annual Rainfall

Climate Variables	Hanover County	Louisa County	New Kent County
Ave. Daily Temp. (F)	55.5°	56.0°	57.9°
Ave. Annual Rainfall (inches)	41.0	41.8	43.2

J. B. Cocke Farm, Hanover County

J. B. Cocke's farm produces cash grains—conventional till corn and full season soybeans. Approximately 7.5 tons of dry, lime-stabilized biosolids were applied to a 19.2 acre field in spring 1997, prior to planting. This field is in a 5-year rotation: one year corn, four years soybeans. Typical yields range from 90 to 105 bushels per acre for corn and from 45 to 55 bushels per acre for soybeans. The field contains Cecil and Appling sandy loam soils with a pH of 6.0. It last had biosolids applied in 1991.

The value of the first year nutrient and lime content and fertilizer application cost savings from the applied biosolids was estimated at almost $71 per acre (Table 6). Most of this value was from credit for the 1.87 tons per acre of lime in the biosolids. No first year value was assigned to the nitrogen content of the biosolids because nitrogen is not normally applied to soybeans. Soybeans, a leguminous crop, fix nitrogen from the soil air and thus do not normally need any nitrogen fertilizer. However, soybeans will take up nitrogen when it is available in the soil rather than expend the extra energy required to fix it from the soil air. Thus, biosolids applied N is not wasted on soybeans.

Table 6. J. B. Cocke, Hanover County: Partial Budgeting Results

	Units	Units credited	Unit price $	Total Acre $
Added costs				
None				
Added returns				
None				
Reduced costs				
182 lbs N/acre	lbs	0.00	0.23	0.00
216 lbs P/acre	lbs	35.00	0.30	10.50
30 lbs K/acre	lbs	30.00	0.14	4.20
Fertilizer application cost savings	acre	1.00	5.50	5.50
1.87 tons/acre of calcitic lime applied expected to last at least 3 years	tons	1.87	27.00	50.53
	Sub-Total			70.73
Reduced returns				
None				
Total savings (loss)				**70.73**

In 1997, the soybean crop averaged 39 bushels per acre (48 bushels per acre in 1996) in this field, in spite of an overall shortfall of rain during the growing season—estimated at 5 to 6 inches per acre below normal.

L. C. Davis Farm, New Kent County

The L. C. Davis farm is a small grains farm in New Kent County with conventional till corn followed by small grains double cropped with no-till soybeans. Davis usually applies commercial fertilizer for corn at the rate of 130 to 140 pounds N, 50 to 60 pounds P, and 30 pounds K. In spring 1997, before corn was planted, an estimated 6.65 tons dry biosolids were applied to a 27.3 acre field, which had not previously had biosolids applied to it. The field contains Bojac and the highly productive Pamunkey silt loam soils and had a pH of 6.4.

The nutrient value and fertilizer application cost savings (for 70 percent of crop needs based on lowered nutrient uptake from drought conditions) and seedbed preparation value resulting from the biosolids application were estimated at almost $57 per acre (Table 7). The net value per acre was about $56 after subtracting costs incurred to till 1.5 acres that were compacted as a result of unloading and spreading the biosolids. Most of the $56 per acre value was from credits for nitrogen and phosphorous content in the biosolids. However, a cost savings of $13.50 per acre was also credited because the biosolids provider incorporated the material into the soil, which reduced seedbed preparation cost.

Table 7. L. C. Davis farm, New Kent County: Partial Budgeting Results

	Units	Units credited	Unit price	Total
Added costs			$	$
Soil compaction from unloading trucks and loading field wagons for distribution	acres	1.5	12.75	19.12
Cost/field acre				**0.71**
Added returns				
None				
Reduced costs				
159 lbs. N/acre	lbs	98	0.23	22.54
247 lbs. P/acre	lbs	42	0.30	12.60
26 lbs. K/acre	lbs	18	0.14	2.55
Fertilizer application cost savings:	acre	1	5.50	5.50
Reduced seedbed preparation required by timely incorporation by applicator	acre	1	13.50	13.50
	Sub-total			56.69
Reduced returns				
None				
Total savings (loss)				**55.98**

The five-year average per acre yields for this field were 85 bushels of corn for the Bojac soil and 160 bushels of corn for the Pamunkey soil. Davis reported per acre field averages of 80 bushels for wheat, 85 bushels for barley, and 35 bushels for soybeans. The 1997 corn crop averaged 61 bushels per acre from the Bojac soil and 117 bushels per acre from the Pamunkey soil. Yields were severely depressed in 1997 due to summer drought: 4 inches of rain compared to 14 inches to 17 inches normally. No measurable differences were found in yields between this field and fields that did not receive biosolids. The field with biosolids looked better early in the summer compared to fields that received commercial fertilizer, but the prolonged drought eventually reduced yields in all fields.

J. R. Smith Farm, Louisa County

The J. R. Smith farm is a cow/calf operation in Louisa County. Smith has 40 cows and 1 bull on 65 acres, approximately 1 animal unit per 1.6 acres. His grazing management consists mostly of non-rotational, open access grazing. Smith had been managing the operation so that cows calve in the spring, but at the time of the study, he was in the process of switching to a fall calving schedule.

Approximately 6.9 tons of non-lime stabilized, dry biosolids were applied to a 15.5 acre fescue and ladino clover pasture in the spring 1997. The pasture contains Cecil and Appling soils with a pH of 6.3 and had never received biosolids. Normally, Smith applies 60 pounds N per acre, 30 pounds P per acre, and 90 pounds K per acre to this field every spring. The nutrient value for the first year and fertilizer application cost savings from the applied biosolids were estimated at almost $41 per acre. Most of this value was from credit for the N, P, and K content of the biosolids (Table 8).

Table 8. J. R. Smith farm, Louisa County: Partial Budgeting Results

	Units	Units Credited	Unit Price	Total
			$	$
Added Costs				
None				
Added Returns				
None				
Reduced Costs				
127 lbs. N/acre	lbs	60	0.23	13.80
367 lbs. P/acre	lbs	30	0.30	9.00
253 lbs. K/acre	lbs	90	0.14	12.60
Fertilizer application cost savings	acre	1	5.50	5.50
	Sub-Total			40.90
Reduced Returns				
None				
Total savings (loss)				**40.90**

Even though the drought in 1997 affected wide areas of the state, Smith's farm received three rains during the summer that were sufficient for good forage growth. Smith reported that the biosolids-treated pasture stayed green all summer while pastures treated with commercial fertilizer did not do as well. Smith estimated that the biosolids-treated pasture received 50 percent more grazing pressure than the untreated pastures. He observed that the treated pasture not only stayed greener during the summer, but also grew back more quickly after grazing, grew well until the fall frosts, and looked better than untreated pastures in December.

Evanylo and Ross conducted a rainfall simulation project during summer 1997 on Smith's pasture where biosolids had been applied. Control areas without biosolids were compared to areas receiving biosolids. The plots with biosolids produced 2,280 pounds of dry matter clipped six weeks after application compared to only 1,380 pounds of forage produced on the control plots during the same time. Greater water infiltration also occurred on the plots receiving biosolids compared to the pasture control area. Simulated rainfall of 3.86 inches was absorbed by the area with biosolids compared to 3.64 inches on the control area: an increase of 0.22 inches water stored.

ENVIRONMENTAL IMPACTS

Water quality problems generally result when the non-point source pollution contributions from multiple land users combine to reach a critical mass, producing observable negative effects. The damages from an individual environmental contamination event on a single site are probably limited in extent and significance. Thus, overall land use and water quality usually must be monitored and understood at the watershed level to define non-point source pollution problems, to identify causes, to effect linkages between land use and environmental pollution, and to implement strategies to solve such problems.

Incorrect application of nutrients coupled with wet weather and steep slopes can result in non-point source pollution to surface and ground waters. As is generally the case with non-point source pollutants (soil delivered to waterways, agricultural chemicals, commercial fertilizers, and livestock manures), the greatest potential for environmental degradation from biosolids applications would result from severe rain storms (4 inches per hour or more) shortly after application. Environmental contamination risk is highest in this situation, especially on cultivated cropland before incorporation because of the greater likelihood that severe thunderstorms will produce significant runoff that contains concentrated quantities of nutrients, organic matter, and microorganisms derived from biosolids and that this runoff will enter surface waters. Scheduling deliveries to take into account expected weather is the best way to minimize this risk.

Pollutant transport from surface applications of biosolids on sandy soils above shallow groundwater will result in greater impact on the quality of local groundwater than similar applications on heavier textured soils where the water table is lower. Similar results can be expected from commercial fertilizer applications under the same circumstances. The rainfall simulation on Smith's farm showed that lower or similar transport rates for total suspended solids, N and P, can occur from applications of biosolids compared to commercial fertilizer (Evanylo and Ross, 1997). The rainfall simulation also indicated that heavy metals and pathogens in runoff from the biosolids-amended crop and pasture plots were no higher than those from the commercially fertilized plots.

The permitting process requires avoiding steep slopes and identifying and protecting sensitive areas such as water bodies and wetlands, which could be negatively affected by direct loading of biosolids. Biosolids companies must meet all permit requirements, including setback regulations, or they can be found in violation of their permits and have them revoked. The Virginia Department of Health, Biosolids Use Regulations stipulate specific setbacks for eight distinct categories: occupied dwellings, water supply wells or springs, property lines, perennial streams and other surface water bodies, intermittent streams and drainage ditches, improved roadways, rock outcrops and sinkholes, and agricultural drainage ditches with slopes equal to or less than 2 percent. The setback rules apply to surface applied, incorporated, and winter applied biosolids. For example, the required setback from sensitive areas ranges from 10 feet along improved roadways to 200 feet from occupied dwellings (Va. Dept. of Health). These buffers represent a practical means to help assure environmental protection.

Except for conservation tillage, conservation practices are very compatible with biosolids applications. Grassed waterways act as both vegetative buffers and conveyance courses to control runoff and non-point source pollution. Buffer strips, required by the Chesapeake Bay Preservation Act, increase infiltration and diminish surface runoff. Field borders function in a similar manner to buffer strips. These conservation practices take up nutrients in runoff and trap sediments and suspended solids. Forested riparian buffers are present in many areas of the Coastal Plains and Piedmont of Virginia. Riparian buffers also function like buffer strips to filter out non-point source pollution. Thus, existing conditions at many agricultural sites are favorable for biosolids applications to take place without significant environmental degradation.

Surface spreading of biosolids by suppliers without incorporation is the most common application practice in Virginia. Incorporation is used to reduce odors, nitrogen volatilization (nitrogen losses to the atmosphere), nonpoint source pollution, and soil compaction resulting from the application. Surface spreading is faster and less expensive than incorporating or liquid injection and avoids a potential conflict with federal farm program participation, but surface spreading may result in violating Department of Health requirements.

Direct injection or incorporation within 48 hours is required by the Virginia Department of Health if a site has less than 60 percent crop residue or living cover or if it is applied to soils subject to frequent flooding. If the remaining crop residues after biosolids are disked in are below the USDA conservation plan required coverage of 30 percent ground cover *after* planting, the farmer could lose program benefits for noncompliance. To avoid possible conflicts, farmers participating in USDA programs requiring conservation plans should review their plans with their local USDA/Natural Resources Conservation Service (NRCS) office.

NUISANCES

Neighbors may complain about the distinct and unpleasant smell of biosolids. Recent scientific evidence indicates that odors can pose a health hazard to individuals who suffer from allergies or who have an immune-compromised physiology (Schiffman). While early incorporation into the soil diminishes the potential for negative effects on neighbors, strong odors reportedly remain even after incorporation when weather is hot and humid. The strength and longevity of the odor on hot, humid days on pastures, where biosolids are not incorporated, is reportedly substantially greater than at other times. In addition, the odors associated with pasture applications are reported to be worse than with cropland applications because biosolids are not incorporated on pastures as they sometimes are on cropland.

Access roads must also be considered when deciding whether to use biosolids. Narrow access roads which have sharp turns, are rutted, or have soft spots will affect the ability of the supplier to deliver the biosolids. The weight of the trucks can also damage roads, especially those that are already soft or rutted. Furthermore, the truck and application equipment traffic may be considered a nuisance. Excessive noise and dust during deliveries in dry weather can also be nuisances.

ALLAYING FEARS

The application of biosolids on agricultural lands has many critics, and the topic remains a very sensitive issue due to concerns for public health and environmental quality. Biosolids contain heavy metals, pathogens, and toxic organic compounds. However, the amounts of these substances contained in the grade of biosolids applied on farms are substantially less than 25 years ago. In addition, the current regulatory requirements that govern the use of biosolids have led the scientific community to perceive associated human health and environmental risks as minimal. Tenenbaum (1997), searching the Medline database, found no scientific articles claiming that biosolids had caused disease in the United States.

Only Class A and B biosolids may be land applied. Class A biosolids, treated to destroy virtually[3] 100 percent of all pathogens, may be land applied without any pathogen related site restrictions. Class B are less treated and can only be applied with site restrictions that effectively meet the level of protection achieved with Class A biosolids. Both classes are treated to greatly reduce pathogens and odor.

Page conducted an extensive study of waste water and biosolids applications to agricultural lands in 1996. While raising some technical issues and recommending further study of Class B biosolids on pastures, the report concluded that

> There have been no reported outbreaks of infectious disease associated with a population's exposure—either directly or through food consumption pathways—to adequately treated and properly distributed reclaimed water or biosolids applied to agricultural land (p.4). . . . While no disposal or reuse option can guarantee complete safety, the use of these materials in the production of crops for human consumption, when practiced in accordance with existing federal guidelines and regulations, presents negligible risk to the consumer, to crop production, and to the environment. . . . Current technology to remove pollutants from wastewater, coupled with existing regulations and guidelines governing the use of reclaimed wastewater and biosolids in crops, are adequate to protect human health and the environment. . . . However, the implementation of regulations and guidelines is where problems are likely to arise (p.13).

Finally, Page pointed out that most biosolids contain more than enough P to meet crop needs when applied at rates calculated to meet crop N needs. Thus, P should be the controlling nutrient, not N, on sites with already high or excessive soil P levels as indicated by soil tests. Under these conditions, the soil essentially becomes saturated with P and any surplus can be transported off-site by surface runoff or leached into the water table. Research currently being conducted compares the mobility of P in biosolids with P in manures and commercial fertilizers. Early results indicate that P in biosolids is less mobile than P in manures or fertilizers (Evanylo, 2000).

SUMMARY

Sludge is an end product of modern wastewater treatment. Increases in the number of people served by sewer systems will inevitably increase the amount of sewage that must be disposed of in some way. The added treatment needed to produce biosolids so that farmers may make use of it makes a lot of sense. Using biosolids reduces farm production costs and can have beneficial soil effects. Recycling biosolids on agricultural lands also reduces the cost of disposal to the public. Biosolids applied on farms typically costs public authorities \$18 to \$25 per ton of semi-dry material while disposal at landfill sites typically costs between \$39 and \$115 per ton of semi-dry material (telephone interviews).

However, no matter how logical the use of biosolids is for agricultural land, it will not work if applicators do not pay attention to the detail of the regulations. Neither will it work if farmers do not know their soils and appropriate agronomic practices. Farmers and biosolids applicators must work together for the results to be beneficial to everyone.

Application laws and procedural requirements for biosolids give Virginia farmers a framework for utilizing a valuable agronomic resource at little or no cost. Carefully coordinated biosolids applications on farms where soils, slopes, and cropping sequence conditions are well matched to take advantage of the beneficial effects, can result in on-farm benefits that far exceed the associated costs. Furthermore, if properly applied, the potential environmental damage is less from biosolids than from commercial fertilizers.

[3] Virtually is used because Class A treatment kills pathogens below levels detectable with current technology.

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