PART XI
Utilization of Organic Wastes as Nutrient Sources and Soil Amendments

Gregory K. Evanylo, Extension Waste Management-Soil and Water Specialist
Gregory L. Mullins, Extension Nutrient Management Specialist

Introduction

Waste products such as manure, biosolids (municipal wastewater sewage sludge), and industrial sludges supply organic matter and nutrients when used as soil amendments. The organic matter in these materials can improve soil tilth and aeration, increase water infiltration into soil and soil moisture holding capacity, decrease soil erosion potential, increase soil cation exchange capacity, buffer soil pH, and promote the growth of beneficial soil organisms. Some of all of the essential plant elements are contained in these materials, but they rarely occur in the proportion required for balanced plant nutrition.

The nutrient and heavy metal contents of organic wastes are highly variable, and analysis of individual wastes must be performed to certify quality and to ensure appropriate application rates. The major environmental concerns associated with the land application of organic wastes are the direct runoff of the organic material and any soluble constituents (e.g., phosphorus) into surface waters and the leaching of nitrate (NO_3^-) to groundwater. Bioavailability of heavy metals and transport of microbial pathogens can pose additional risks if waste material quality and proper management is not assured.

Sources of organic wastes

Processes that generate wastes

Manure

Livestock (beef and dairy cattle, swine) and poultry (broilers, layers, turkeys) operations generate animal waste (feces and urine) that must be collected and stored prior to land application. Some animal waste handling systems (e.g., composting, anaerobic lagoons) are designed to treat the waste by reducing pathogens, odors, and nitrogen content and increasing organic matter stability, but most systems are simply collection and storage facilities. Descriptions of manure types associated with beef and dairy cattle, swine, and poultry are presented in Table 1.

Table 1. Manure Collection Systems (Source: Evanylo, 1994)

Type	Description	Animal Type
Solid without bedding	Feedlot, scraped	Beef and dairy cattle, swine
Solid with bedding	Tramp shed	Beef and dairy cattle
Anaerobic lagoon	Solids settled on bottom	Beef and dairy cattle, swine
Anaerobic lagoon sludge	Supernatant of a non-agitated waste lagoon	Beef and dairy cattle, swine, poultry
Compost	Controlled aerobic decomposition	Beef and dairy cattle, swine, poultry
Liquid manure slurry	Pit storage of wash waters	Beef and dairy cattle, swine, poultry
Deep pit	Two-story poultry house; manure falls through the caged 2nd floors to 1st	Poultry
Solid without litter	Manure collection gutters under poultry are scraped each week	Poultry
House litter	Manure falls onto bedding and is removed after one or more flocks	Poultry
Stockpiled litter	Same as house litter, but stockpiled until needed	Poultry

<u>Biosolids</u>

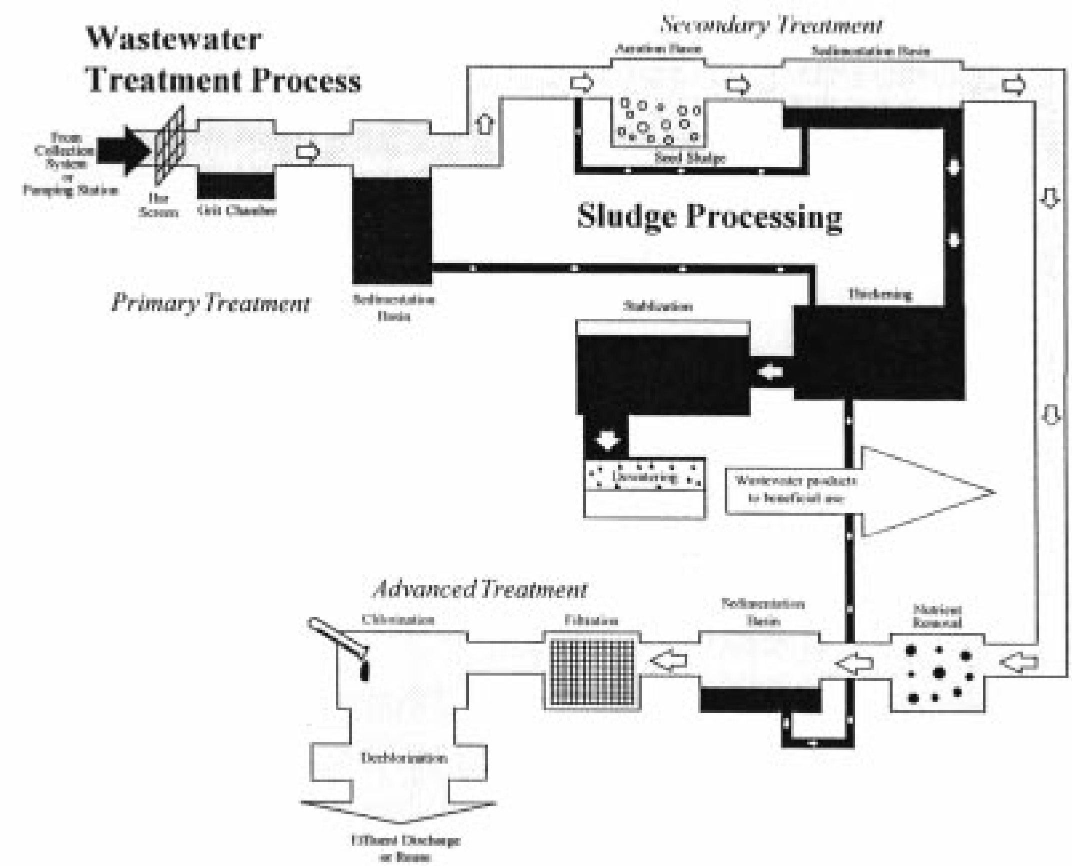
Biosolids are municipal wastewater sewage sludges that have been treated to permit their safe and beneficial application to soil for agricultural purposes. Biosolids are the materials remaining after treatment facilities purify wastewater from homes, businesses and industries. In some communities, runoff from roads, lawns and fields is also included. Biosolids are composed of inorganic constituents, such as macro- and micro-nutrients and non-nutrient trace elements, organic compounds, and microorganisms, including pathogens and parasites.

With minor exceptions, such as pretreatment required by industrial wastewater and sewer ordinances, treatment plants have little control over the material they process. They must accept all incoming wastewater and purify it before discharging the effluent back into the environment. The wide variety of incoming wastewater and available treatment technologies determines the volume and composition of wastewater treatment plant biosolids.

Figure 1 illustrates a generalized wastewater treatment process used to produce biosolids. As wastewater enters the plant, a screen removes large objects and a settling chamber removes grit. The wastewater then travels through the primary sedimentation basin where much of the solid matter is separated from the liquid. The secondary treatment process removes additional solids and some dissolved nutrients from the liquid. Advanced treatment further removes dissolved nutrients, then filters and disinfects the wastewater. Solids are combined, thickened, and stabilized. The stabilization process reduces pathogen numbers and the properties that attract vectors (i.e., disease-spreading animals) and readies the biosolids for dewatering. Once dewatered, the biosolids are ready to be land applied.

The State Department of Health is responsible for administering and enforcing the Biosolids Use Regulations (12 VAC 5-585, 32.1-164.5 of the Code of Virginia), under which most land application programs operate in Virginia. Further details regarding wastewater and biosolids treatment processes, regulations, and agricultural land application practices can be found in the Virginia Cooperative Extension Publication 452-301 through 452-304, a series on agricultural land application of biosolids in Virginia (Evanylo, 1999).

Figure 1. Schematic of Typical Wastewater Treatment Process.



Industrial sludge

Many industries produce wastewater that is processed in the same manner as municipal wastewater. The solids removed from these industrial wastewaters can be land applied if they meet the same stringent standards for biosolids. Some of the industries whose solids are often beneficially recycled onto land include textile mills (textile scrubber wastes), fermentation (brewery wastes containing yeast), and wood processing (paper mill sludge). The Virginia Department of Environmental Quality issues permits to applicators of industrial wastes.

Waste characteristics

Manure

Animal manure is a mixture of metabolic products such as urea and uric acid, living and dead organisms, and partially decomposed residues from the original feed. Nutrient content of manure varies with: (1) animal type and age, (2) composition of the feed, (3) amount of bedding and water added or lost, (4) method of manure collection and storage, and (5) length of time the manure is stored before field application. On a typical livestock farm about 75% of the nitrogen (N), 60-70% of the phosphorus (P), and 80-85% of the potassium (K) fed to animals are excreted in the manure. Examples of nutrient contents in fresh manures are presented in Table 2. The average concentrations of N, P, and K in poultry manures are higher than in other livestock wastes. The relative proportion of N:P in all fresh manures is generally about 3:1 to 4:1.

Table 2. Manure Production and Nutrient Content (Source: Barker, 1980)

Animal	Animal Weight Lbs	Fresh Manure lbs/yr	Nutrients in Fresh Manure N	P	K
			——lbs/ton——		
Dairy	640	37,400	12	3	12
Beef	440	24,200	12	3	8
Swine	45	3,080	12	3	5
Caged layer	2	100	28	9	10
Dry litter:					
Broiler	1	15	52	18	28
Turkey	7	48	36	14	12

The greatest impact on nitrogen content of manures is loss of ammonia (NH_3) through volatilization during handling and storage. As much as 50-60% of the original nitrogen may be lost during handling and storage (Table 3). Generally, more atmospheric nitrogen loss will occur the longer the manure is stored. Nitrogen loss from manure reduces the ratio of N:P in manure to be applied to land to about 1:1 to 1.5:1 because phosphorus is conserved in manure during collection and storage. The consequence of this is that higher amounts of phosphorus than required by crops are supplied when manures are applied at rates that supply the necessary amounts of nitrogen.

Table 3. Nitrogen Loss and Retention From Manure Storage and Handling Systems (not including loss from field application) (Vanderholm, 1975)

Storage and handling system	Amount Lost (%)	Amount Remaining (%)
1. Manure liquids and solids hauled daily	15-25	75-85
2. Manure liquids and solids held in a covered, essentially watertight structure	20-30	70-80
3. Manure liquids and solids held in an uncovered, essentially watertight structure	30-40	60-70
4. Manure liquids and solids held in a storage pond; contents are agitated before spreading	30-40	60-70
5. Manure and bedding held in roofed storage	30-40	60-70
6. Manure without bedding held in unroofed storage; leachate is lost; solids are spread	45-55	45-55
7. Manure stored on open feedlot surface; only the solids are spread	50-60	40-50
8. Poultry layer manure stored in roofed shallow pit cleaned every 3 to 6 months	30-40	60-70
9. Broiler manure on sawdust or shavings in warm, humid climate; house cleaned every 4 months	45-55	45-55
10. Poultry layer manure in cool humid climate; stored in roofed, fan-ventilated pits cleaned yearly	50-60	40-50

Table 4 shows the wide range in nutrient composition of manures sampled from numerous farms in Virginia following the effects of considerable collection and storage losses of nitrogen. It is not advisable to use average nutrient contents when determining manure application rates because of the great variability in the values. The most accurate way to determine nutrient content of manure is by laboratory analysis. The minimum analysis should include: percent dry matter, ammonium nitrogen (NH_4-N), total Kjeldahl nitrogen (TKN), phosphorus (as P or P_2O_5) and potassium (as K or K_2O). Organic nitrogen can be calculated as the difference between total Kjeldahl nitrogen and ammonium nitrogen (i.e., TKN - NH_4-N). Nitrate nitrogen is normally so low in manure that its concentration is not determined.

Biosolids

Biosolids vary widely in their chemical, biological, and physical properties. The determining factors include the source and composition of the sewage, the treatment system, the extent to which the material is digested and stabilized, and the handling method between processing and application to the soil.

Nineteen studies of municipal biosolids from 45 sites in seven southern states demonstrated enormous variability in composition (Table 5). Because composition varies greatly, each type of biosolid intended for use on agricultural land must be analyzed separately. The concentrations of nitrogen and phosphorus in biosolids are similar to those in animal manures, while potassium in biosolids is much lower than those in most animal wastes.

Although the source of the biosolids affects its nitrogen content, the type of biosolids treatment may be just as important a determining factor. Median total nitrogen concentrations in biosolids subject to various types of treatment were 4.8% for aerobic digestion, 4.2% for anaerobic digestion, and 1.8% for combined lagooned, primary, tertiary, and other unspecified processes (Sommers et al., 1977).

Most biosolids contain both organic and inorganic forms of nitrogen. Inorganic nitrogen is normally present as either ammonium (NH_4^+) or nitrate (NO_3^-), with the proportion of each being dependent on the waste treatment process employed. Aerobic digestion results in mineralization of organic N to NH_4^+ and nitrification of NH_4^+ to NO_3^-. In contrast, only NH_4^+ is present in anaerobically digested biosolids. In anaerobically digested biosolids, about 20 to 50% or more of the N is NH_4-N, with very little NO_3-N. If wastes are stored in a lagoon before application, inorganic N can be lost through ammonia (NH_3) volatilization and denitrification.

In contrast to nitrogen, most of the phosphorus in biosolids is in the inorganic form. The inorganic phosphorus content of eight biosolids analyzed by Sommers et al. (1976) averaged 73% of the total P content. Biosolids are generally considered poor sources of plant available potassium, primarily due to the low concentrations of potassium in biosolids. Potassium is a soluble constituent in wastewater sewage and is largely lost in the treated and discharged effluent.

Table 4. Mean, Minimum and Maximum Amounts of NITROGEN, PHOSPHORUS, AND POTASSIUM in Manure from Various Animal Types and Handling Systems Tested by the Virginia Tech Water Quality Laboratory, January 1989 to November 1992. (Source: E.R. Collins)

Manure Type	TKN		NH_4-N		P_2O_5		K_2O	
(No. of samples)	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Liquid:								
Dairy (434)[a]	22.6	1.0-52.5	9.6	0.0-44.6	12.1	0.0-37.2	18.9	0.0-48.8
Swine (109)[a]	10.0	0.6-58.5	5.3	0.3-25.8	5.7	0.4-61.5	5.7	0.1-23.5
Poultry (14)[a]	51.1	4.5-89.1	33.0	0.6-66.3	41.0	0.6-100.3	30.5	2.0-53.4
Semi-solid:								
Dairy (46)	10.5	3.4-23.6	3.2	0.1-7.8	6.1	2.2-19.1	8.7	2.0-16.0
Beef (18)	12.8	7.8-23.9	2.6	0.2-15.5	6.7	2.5-14.6	11.8	4.4-30.9
Dry:								
Broiler Litter (254)	62.6	5.7-99.5	11.8	0.2-25.8	62.1	22.7-119.4	28.6	3.3-53.3
Layer/breeder (54)	36.5	9.1-110.6	9.0	0.2-29.6	65.1	9.8-149.7	24.2	4.8-50.2

[a] Values presented in lbs/1000 gals. All other values in lbs/ton.

Table 5. Properties of Municipal Biosolids from Several Southern States (King et al., 1986)

	Number of samples	Range	Mean	Median[a]
Solids content of liquid biosolids (%)	13	0.6-7.1	3.8	4.4
Ash (% of solids)	16	19-59	43.0	47.0
pH	8	5.4-7.0	6.1	5.9
Total N of solids (%)	21	0.6-7.5	3.0	2.6
Total N[a] of liquid fraction (mg/L)	13	7-730	280	290
Total P of solids (%)	40	0.4-5.3	1.8	1.6
Total K of solids (%)	40	< 0.1-1.0	0.2	0.2
Total Ca of solids (%)	39	< 0.1-6.0	1.5	1.3
Total Mg of solids (%)	39	0.1-0.5	0.2	0.2

[a] Predominantly NH_4-N.

<u>Industrial sludge</u>

Data on solids, ash, and macronutrients in sludges generated by textile mills, fermentation processing, and wood processing are summarized in Table 6. The nitrogen content of textile and fermentation wastes is generally comparable to that of municipal biosolids, but the nitrogen content of wood processing wastes is usually much lower. The concentrations of other macronutrients are generally low compared to manures and biosolids.

Factors that affect nutrient availability

The availabilities of nutrients in organic wastes are due to differences in composition and form of nutrients. The following sections on specific nutrients are generally true for all organic wastes.

<u>Nitrogen</u>

Nitrogen occurs primarily in two forms in organic wastes - inorganic N, largely as ammonium (NH_4^+), and organic N. The ammonium nitrogen is immediately available to crops, but it can readily be converted to ammonia (NH_3), which is easily lost to the atmosphere. Organic nitrogen must be mineralized to ammonium by soil microorganisms before it can become available for uptake by plants.

Table 6. Properties of Industrial Wastes from Several Southern States (King et al, 1986)

	Textile mill sludge		Fermentation sludge		Paper mill sludge	
	Median	Range	Median	Range	Median	Range
Solids content of liquid wastes (%)	6.9	0.6-13.5	19	13-54	12.4	——
Ash (% of solids)	43	14-76	49	37-66	45	6-67
Total N of solids (%)	2.8	1.0-7.9	3.5	2.0-7.0	0.4	0.3-2.3
Total N[a] of liquid fraction (mg/L)	22	16-112	340	19-680	——	——
Total P of solids (%)	0.9	0.3-2.0	0.2	0.1-0.7	0.1	<0.1-0.30
Total K of solids (%)	0.2	0.1-0.3	0.1	<0.1-0.2	0.1	<0.1-9.3
Total Ca of solids (%)	0.5	0.1-0.8	5.2	<0.1-9.8	0.8	0.3-9.8
Total Mg of solids (%)	0.2	0.1-0.4	<0.1	<0.1-0.2	0.1	<0.1-0.7

[a] Predominantly NH_4^+-N

Nitrate (NO_3^-) concentrations in manure and biosolids are usually low and contribute little to the immediately available plant nitrogen pool; however, nitrate-N is rapidly produced by the microbial process of nitrification from ammonium either added directly to the soil or mineralized from organic nitrogen. The resulting inorganic nitrogen is available to the crop as ammonium and nitrate.

In summary, factors that determine the rate and timing of nitrogen availability to crops from organic wastes include:
1. Amount of NH_4-N in the manure;
2. Application method and resulting atmospheric loss of NH_3; and
3. Rate of mineralization of organic N to plant available forms.

Organic wastes should not be applied in excess of the agronomic N rate, which is the rate required to supply the nitrogen needs of the target crop. Therefore, the application rate should be based on the amount of plant available N in the waste unless another constituent (e.g., P, lime equivalent) limits the application rate to a greater extent.

Ammonia (NH_3) is extremely volatile. Its loss during storage and from the soil surface after application may be as great as 70% of the total amount of manure or biosolids nitrogen. All of the ammonium is immediately available for plant utilization. The value and amount of nitrogen utilized by the crop will depend on how much ammonia had been conserved during handling. The values in Table 7 and 8 provide estimates on what fractions of ammonium in organic wastes are available for plant uptake under different incorporation timing schemes.

Table 7. Fraction of Ammonium Nitrogen in Animal Manure Considered to be Available for Plant Uptake (Source: Virginia Department of Conservation and Recreation, 1995)

Liquid Method of application	Semi-solid manure	Manure slurry	Lagoon liquid	Dry litter
		Fraction of available N		
Injection	——-	0.95	0.95	——-
Broadcast with immediate incorporation	0.75	0.75	0.90	0.90
Incorporated after 2 days	0.65	0.65	0.80	0.80
Incorporated after 4 days	0.40	0.40	0.60	0.65
Incorporated after 7 days	0.25	0.25	0.45	0.50
Irrigation without incorporation	——-	0.20	0.50	——

Table 8. Fraction of Ammonium Nitrogen (NH_4-N) in Biosolids Considered to be Available for Plant Uptake (Source: Virginia Department of Health, 1997)

Management practice	Biosolids pH<10	Biosolids pH>10
	Fraction of available N	
Injection below surface	1.00	1.00
Surface application with:		
Incorporation within 24 hours	0.85	0.75
Incorporation within 1-7 days	0.70	0.50
Incorporation after 7 days	0.50	0.25

Mineralization of organic nitrogen to a plant-available form occurs in two phases. The first phase includes the less resistant organic nitrogen, which mineralizes during the first year of application. The second phase includes the more resistant residual organic nitrogen, which mineralizes very slowly in future years. Repeated yearly applications to the same field result in an accumulation of a slow-release (residual) manure or biosolids nitrogen source from present and past applications.

Available nitrogen from mineralization of organic nitrogen can be estimated using coefficients determined from experimentally-derived decay series. The fractions listed in Tables 9 and 10 are for the mineralization of manures and biosolids. As an example, the decay series of 0.35-0.12-0.05 for dairy manure means that 35 percent of the organic nitrogen is mineralized during the year applied, 12 percent of the initial organic nitrogen remaining after the first year is mineralized during the second year, and 5 percent of the initial organic nitrogen remaining after the second year is mineralized during the third. The nitrogen remaining after the first year that will become available for plant use in subsequent years is called residual nitrogen.

There are no universal decay series across the United States because the rate of microbial breakdown depends primarily upon soil characteristics and climatic conditions. The decay series is for the stable organic nitrogen only and does not include ammonium, which is 100% available.

Table 9. Available Fractions of Remaining Organic Nitrogen During the Three Years after Application of Various Animal Manures (Source: Virginia Department of Conservation and Recreation, 1995)

Animal Type	Year One	Year Two	Year Three
	Fraction of Available N		
Dairy & Beef	0.35	0.12	0.05
Swine	0.50	0.12	0.05
Poultry	0.60	0.12	0.05

Table 10. Available Fractions of Remaining Organic N During the Three Years After Application of Variously Treated Biosolids (Source: Virginia Department of Health, 1997)

	Year One	Year Two	Year Three
	Fraction of Available N		
Primary	0.30	0.15	0.07
Waste activated	0.40	0.20	0.10
Aerobically digested	0.30	0.15	0.08
Anaerobically digested	0.20	0.10	0.05
Lime stabilized	0.30	0.15	0.08
Composted	0.10	0.05	0.03

Calculations of plant available nitrogen (PAN) from organic waste will include the portion of the ammonium that is not lost by volatilization and a portion of the stable organic nitrogen. The amount of PAN in organic wastes can be estimated by:

$$PAN = NO_3\text{-}N + x\,(NH_4\text{-}N) + y\,(\text{Organic N}).$$

Where x is the fraction of NH_4-N that does not volatilize (values found in Tables 7 and 8) and y is the fraction of organic N expected to mineralize (values found in Tables 9 and 10).

Phosphorus and potassium

Manure and biosolids are excellent sources of phosphorus (P). Much of the phosphorus in manure may be organically-complexed and, like organic nitrogen, must mineralize before it is available for utilization by plants. Organic phosphorus in wastes mineralizes rapidly and is readily plant-available. The phosphorus in biosolids, which exists largely in inorganic forms complexed by iron compounds, may be somewhat less plant-available than the phosphorus in manures. Ultimately, the plant availability of phosphorus from organic wastes is controlled by soil chemical reactions in the same way that soil chemistry controls the availability of phosphorus from inorganic fertilizer. The availabilities of phosphorus in manure and biosolids are estimated as 90 to 95% and 50 to 95% of fertilizer phosphorus, respectively.

Manure potassium (K), chiefly present in the urine as inorganic potassium, is chemically equivalent to fertilizer potassium (i.e., it is available for plant growth in the year it is applied). Biosolids are generally poor sources of plant available potassium due to its presence in low concentrations; however, potassium in biosolids is normally assumed to be 100% plant available.

Essentially all of the potassium and most of the phosphorus supplied in organic wastes is plant-available. The amount of manure required to meet crop phosphorus and potassium requirements can be calculated by using a combination of soil testing and manure analysis.

Secondary and micronutrients

Manures and biosolids contain secondary macronutrients (i.e., calcium, magnesium and sulfur) and micronutrients (i.e., manganese, iron, copper, zinc, boron, molybdenum) which are not commonly applied in commercial fertilizer unless specifically recommended. Organic wastes provide some insurance against yield reductions due to insufficient secondary and trace nutrients when the cost of applying such nutrients in commercial fertilizer cannot be justified because of the lack of evidence of a consistent yield response.

Some trace elements may accumulate to concentrations in the soil that are phytotoxic (e.g., zinc, copper, nickel) or in plants that are toxic to livestock (e.g., molybdenum) or humans (e.g., arsenic, cadmium) if organic wastes containing high concentrations of these trace elements are applied. The permissable concentrations of these trace elements in biosolids and industrial sludges are strictly regulated. Concentrations of these elements in manure do not normally pose health, environmental, or agronomic risks, but their soil accumulation and bioavailability should be monitored where continuous applications of some types of manure have been made.

Lime

The addition of lime in some biosolids stabilization treatment processes can provide calcium carbonate equivalencies of 10-50 percent. It is possible that the lime potential of these biosolids can limit waste application rates on poorly-buffered, coarse-textured (i.e., sandy) soils having a high soil pH. Preventing the pH of these soils from rising above about 6.8 is necessary to eliminate the risk of inducing micronutrient (e.g., manganese in small grains and soybean, zinc in corn) deficiencies.

Best management practices

Wastes must be well managed to reap agronomic benefits and to reduce environmental and health risks. Overall, the most important factors in preventing nutrient loss include field application methods, timing of application, and application rate.

Application rate

Waste application rates should balance nutrient content in the waste with crop nutrient demands based on realistic yield goals. The ratio of $N:P_2O_5:K_2O$ in organic wastes usually does not match the ratio of the nutrients needed by the crop; however, an appropriate rate can be calculated by basing it on the nutrient that is the most limiting to crop growth. Generally, the nutrient that determines the overall application rate is nitrogen.

The total phosphorus application rates are generally much higher than crop needs when a waste application rate is based on plant available nitrogen (PAN). For example, biosolids having 1.3% PAN and 1.0% total P (2.3% P as P_2O_5) applied to supply 150 lbs PAN per acre would also apply 115 lbs P or 265 lbs P_2O_5 per acre. Crop nitrogen removal is normally two to four times higher than phosphorus removal. Therefore, continuous application of wastes based on agronomic nitrogen rates will build soil phosphorus concentrations many-fold higher than required. (See Nutrient Removal by Crops table, Part VII Soil Testing & Plant Analysis) Phosphorus runoff from soils where continuous applications of organic wastes have built soil phosphorus to excessive levels poses an environmental threat to the health of surface waters. It is advisable to apply wastes at rates recommended by the most limiting of soil test P/crop P removal or agronomic N rate.

Application method

Soil incorporation captures more of the NH_4-N than surface application of waste. Research has shown that 20% of the nitrogen may be lost to the atmosphere in the first six hours after spreading manure on the soil surface, and nearly 50% can be lost after four days (Table 11). Plowing or disking of manure, biosolids, and other sludges into the soil shortly after application, or injecting the waste into the soil reduces such losses.

Table 11. Relative Effectiveness of Manure in Increasing Crop Yields as Influenced by Time Between Spreading and Plowing Under (Salter and Schollenberger, 1939)

Treatment	Relative value in increasing crop yield (Average of 34 experiments)
Manure plowed under immediately	100
Manure plowed under 6 hr after spreading	85
Manure plowed under 24 hr after spreading	73
Manure plowed under 4 days after spreading	56

Application timing

Wastes should be applied as closely as possible to the time of maximum crop nutrient uptake to ensure that the nitrogen will be available to crops rather than lost to surface water, groundwater, or the atmosphere. Fall and winter applications of biosolids and manures should be avoided unless actively growing winter cover crops are present. Without an actively growing crop, nitrate nitrogen may leach to groundwater or be transported to surface water. Surface applications of biosolids and manures containing high concentrations of ammonium nitrogen during hot dry periods can result in large losses of ammonia.

Cropping systems

The most appropriate crops for the use of manure and biosolids are those that have relatively high nitrogen requirements (i.e., corn, small grains, pasture grasses). Application of manure and biosolids to legumes such as soybean or alfalfa is generally not an efficient use of nitrogen, since rhizobial bacteria associated with the roots of legumes fix N from the atmosphere; however, if no other appropriate crop is available, soybean and alfalfa will effectively use manure nitrogen.

Biosolids and industrial sludges are particularly useful in the reclamation of surface-mined areas, sand tailings piles, borrow pits, and other disturbed land areas. Soils on these sites lack organic matter and nitrogen, they are usually acid (low pH) and low in available phosphorus and potassium, and have poor physical structure. The potential for groundwater pollution from biosolids application may be greater on surface-mined sites than on undisturbed sites, unless a vegetative cover is established, because the soil strata may be disturbed well below the surface.

Site management

Protection of water resources from nutrients, especially nitrogen and phosphorus, and pathogens must be considered when handling and utilizing manures and biosolids. Drainage from feedlots and storage lagoons should not be permitted to flow into streams and reservoirs. Proper field management must begin at the unloading site. Soil compaction may occur due to the weight of the wastes and vehicles transporting the material if soil moisture is high.

Steps should be taken to prevent soil erosion as a direct result of land application practices. Detrimental water quality impacts from manures and biosolids can be avoided by employing conservation tillage practices that reduce erosion and prevent the movement of sediment and waste constituents to surface water. Water pollution problems caused by movement of waste constituents in runoff water can be minimized by use of grassed buffer strips along waterways adjacent to application sites.

Liquid waste injection practices can affect the amount of soil erosion that occurs. Driving the applicator vehicle across the slope instead of up and down reduces erosion. Injecting the liquid wastes up and down the slope provides channels for water and intensifies erosion potential in the same way as plowing or cultivating up and down the slope. Using injectors in muddy soils results in much the same type of soil structural damage as plowing when the soil is too wet. Clay soils, in particular, become cloddy and adequate seedbed preparation is very difficult if stirred when wet. Applicator vehicles with high flotation tires reduce compaction damage in the upper zone of wet soils; however, compaction in the 12 to 24 inch depth is a function of total axle weight.

The environment must not be degraded by allowing waste constituents to leave the site by overland flow. Manure or biosolids should not be spread on frozen ground, near sinkholes or rock outcrops, or on steep slopes where nutrients can leach or runoff into ground- or surface water. Even sites with a very slight slope can cause severe runoff problems from rain or melting snow on top of frozen ground.

In summary, the relative risks of all waste application options must be considered in arriving at policies and practices to manage their use on land effectively. Awareness of the agricultural, health, and environmental benefits, costs, and impacts are critical to developing publicly acceptable management programs.

References

Barker, J.C. 1980. Livestock manure production rates and approximate fertilizer content. North Carolina Agric. Ext. Service Leaflet No. 198. Raleigh, NC.

Evanylo, G.K. 1994. Mineralization and availability of nitrogen in organic waste-amended mid-Atlantic soils. P.77-103. In S. Nelson and P. Elliott (ed.) Perspectives on Chesapeake Bay, 1994: Advances in estuarine sciences. CRC Publication No. 147. Chesapeake Research Consortium, Inc., Edgewater, MD.

Evanylo, G.K. 1999a. Agricultural land application of biosolids in Virginia: Production and characteristics of biosolids. Virginia Coop. Ext. Publ. No. 452-301. 6 p.

Evanylo, G.K. 1999b. Agricultural land application of biosolids in Virginia: Regulations. Virginia Coop. Ext. Publ. No. 452-302. 8 p.

Evanylo, G.K. 1999c. Agricultural land application of biosolids in Virginia: Managing biosolids for agricultural use. Virginia Coop. Ext. Publ. No. 452-303. 8 p.

Evanylo, G.K. 1999d. Agricultural land application of biosolids in Virginia: Risks and concerns. Virginia Coop. Ext. Publ. No. 452-304. 6 p.

King, L.D., R.W. Taylor, and J.W. Shuford. 1986. Macronutrients in municipal and industrial sludges and crop response to sludge additions. p. 11-19. In L.D. King (ed.) Agricultural use of municipal and industrial sludges in the southern United States. Southern Cooperative Series Bulletin 314. North Carolina State University, Raleigh, NC.

Salter, R.M. and C.J. Schollenberger. 1939. Farm manure. Ohio Agric. Exp. Sta. Bull. No. 605.

Sommers, L.E. 1977. Chemical composition of sewage sludges and analysis of their potential use as fertilizers. J. Environ. Qual. 6:225-239.

Sommers, L.E., D.W. Nelson, and K.J. Yost. 1976. Variable nature of chemical composition of sewage sludges. J. Environ. Qual. 5:303-306.

Vanderholm, D.H. 1975. Nutrient losses from livestock waste during storage, treatment, and handling. In Proceedings of the Third International Symposium on livestock wastes. American Society of Agricultural Engineering.

Virginia Department of Conservation and Recreation. 1995. Virginia nutrient management standards and criteria. Richmond, VA. 64 p.

Virginia Department of Health. 1997. Biosolids use regulations. 12 VAC 5-585, 32.1-164.5 of the Code of Virginia. Richmond, VA. 60 p