

XII. Manure Utilization as a Crop Nutrient Element Source

Manure utilization is best managed based on its content of plant-available nutrient elements. The nutrient element content of manure varies depending on:

- source
- moisture content
- amount of bedding or other material that is mixed with the manure
- whether the manure has been composted

Assaying a composite manure sample for its nutrient element content determines what the appropriate application rate would be. As with other nutrient element sources, including inorganic commercial fertilizers, application rates should be based on soil test results, soil type, and crop requirement.

If manure is used as the sole plant nutrient element source, soil phosphorus levels will gradually increase, and after several years, are likely to reach very high levels. In such situations, phosphate-enriched soil can be moved by drainage waters into surface waters resulting in water quality problems. Very high levels of soil test phosphorus can be avoided by basing manure applications on phosphorus rather than nitrogen content before the soil phosphorus levels reach the “Very High” soil test level. As a result of concerns about water quality, among other things, operators of confined animal facilities are required to develop comprehensive nutrient element management plans. These plans along with monitoring requirements, ceiling concentrations, and soil loading with respect to copper and zinc are described in Regulation 61-43, *Standards for the Permitting of Agricultural Animal Facilities*, dated June 26, 1998, and apply to swine and other animal facilities.

XIII. Land Application of Nonagricultural Waste Products as Crop Nutrient Element Sources

1. Regulations

Many agricultural, industrial, and municipal waste materials are suitable for application to crop land that contributes to nutrient element utilization through a natural recycling process. In addition, land application of nonhazardous wastes has many environmental advantages compared to land filling and other disposal methods that fail to capture the useful resources present in these wastes. Manures, as well as other agricultural wastes, have been land applied since agriculture began. However, land application of nonagricultural wastes is relatively new, and special regulations have been developed to ensure the protection of public and environmental health and safety.

The United States regulations for organic production require that raw animal manure must be composted unless it is applied to land used for a crop not intended for human consumption, or is incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with soil; or is incorporated into the soil not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles. See 7 CFR 205.203©(1) and (2) [Organic Trade Association – Manure Facts].

Sewage sludge, also called "wastewater biosolids," and many industrial sludges and wastes contain nitrogen as well as other plant nutrient elements that can be used by most crops, including lawns and gardens. The South Carolina Department of Health and Environmental Control (DHEC) regulates land application of sewage sludges and nonhazardous solid wastes in South Carolina. DHEC's guidelines for sludge are given in *Beneficial Use of Wastewater Biosolids* dated February 1996. The state regulations covering land application of solid wastes is covered by regulation R. 61-107.15, *Solid Waste Management: Land Application of Solid Waste*.

Furthermore, sewage sludge is not permitted in organic agriculture. The use of sewage sludge, also known as biosolids, which comes from treated municipal waste water and other sources, is one of the three processes completely banned in organic production. The other two other banned processes are the use of any genetically modified organisms and the use of irradiation [Organic Trade Association – Manure Facts].

Cropland application of waste regulations and guidelines are designed to protect human health and the environment while allowing for beneficial recovery of contained plant nutrient elements. The regulatory requirements and guidelines are described in the publications mentioned above.

The below discussions address only the nutrient element management aspects of land application of wastes that are declared by DHEC to be nonhazardous, and therefore, appropriate for land application. In many cases, waste management plans stipulate waste application rates based on the agronomic considerations described in this publication.

2. Nutrient Element Management

From the standpoint of nutrient management practices, wastes should be managed with the same considerations as for chemical fertilizer, liming materials, and other nutrient element sources with regards to nitrogen rate, time of application and maintenance of soil pH. Wastes should be applied so as not to exceed the agronomic rate.

Agronomic rate has been defined in government regulations as “the amount of waste materials that will provide all the nitrogen needs of the crop (in South Carolina that means the nitrogen recommendations given in this publication), while minimizing the amount of nitrogen that leaches below the root zone to groundwater.” Waste materials must be chemically analyzed to determine their nitrogen content as well as the concentrations of other constituents that may affect the application rate.

The agronomic rate for waste materials, such as lime-stabilized sewage sludge and alkaline waste materials that have significant liming potential, is determined by the lime requirement of the soil and the calcium carbonate equivalent of the waste material. In special cases, the agronomic rate for a waste material may be determined by soluble salt level, boron or sodium concentration. The soil pH should be monitored and care taken not to allow over-liming when alkaline- or lime-stabilized sludges are applied. If the soil pH increases much above 6.5, zinc and manganese deficiencies may occur. If assistance is needed to determine the agronomic rate for a waste application, a local Extension Office should be consulted.

For those waste materials that have significant liming potential, the agronomic rate is to be determined by both the lime equivalent and the lime requirement of the soil on which the waste material is to be applied.

When the nitrogen content of a waste material determines its agronomic rate, application rates should be according to Clemson's crop-specific recommendations for nitrogen as given in this publication.

Sewage sludge and similar biosolids contain both organic and inorganic forms of nitrogen, with most of the nitrogen in sludge being in the organic form that is unavailable to plants until it is converted to an inorganic form. The inorganic nitrogen forms (ammonium and ammonia) are considered plant-available nitrogen (PAN). Ammonia-nitrogen is subject to loss by volatilization with the extent of loss being greater for alkaline materials left on the soil surface. By injection below the soil surface, ammonia losses are minimized. The Ammonia Volatilization Factor for estimating potential ammonia volatilization losses by method of soil application are:

| Soil Application Method | Ammonia Volatilization Factor |
|---|--------------------------------------|
| Surface spreading | 0.50 |
| Surface spreading followed by incorporation | 0.75 |
| Subsurface injection | 1.00 |

In order to obtain the percentage of ammonium that will be plant-available nitrogen (PAN), the ammonia (including ammonium) concentration is multiplied by the *Ammonia Volatilization Factor*.

The small amount of nitrate-nitrogen that is plant-available nitrogen (PAN) is another inorganic form of nitrogen present in sludge. Both ammonium and trapped ammonia in the soil are converted to nitrate within a few days to a few weeks, depending on soil temperature and moisture, by naturally occurring soil microorganisms.

After sludge is soil applied, a portion of the contained organic nitrogen is mineralized, converted from organic to inorganic nitrogen forms of nitrogen (ammonium, ammonia, and nitrate), thus the released nitrogen becomes crop available during the growing season. These inorganic nitrogen forms produced during decomposition of the organic substances in sludge are identical to the ammonium, ammonia, and nitrate found in commercial fertilizers. However, there is a major uncertainty in estimating the mineralization rate of the organic nitrogen forms, and therefore, the agronomic rate. An estimate of the mineralization rate is needed in order to calculate the plant-available nitrogen (PAN), and subsequently, the agronomic rate for the sludge application. Crude estimates of the potential mineralization rates for various sludges are:

| Treatment Process | Mineralization Factor |
|---|------------------------------|
| Unstabilized primary and waste activated sludge | 0.4 |
| Alkaline stabilized | 0.3 |
| Aerobically digested | 0.3 |
| Anaerobically digested | 0.2 |
| Composted | 0.1 |

Nitrogen content is expressed as percent total Kjeldahl nitrogen (%TKN) that includes both organic and inorganic forms of nitrogen. Both nitrate- and ammonium-nitrogen concentrations are subtracted from the TKN value to obtain its organic nitrogen concentration. The organic nitrogen concentration, multiplied by the mineralization factor, gives the obtained contribution of organic nitrogen to the plant-available nitrogen (PAN). For example, the percent PAN from the organic fraction (percent mineralized during the growing season) is:

mineralized organic nitrogen = mineralization factor X (%TKN - % nitrate - % ammonium)

The three sources of nitrogen, nitrate, ammonium (adjusted for volatilization), and organic nitrogen subject to mineralization, are added in order to obtain the % PAN for the sludge.

Following is a sample calculation for an aerobically digested sludge found to be:

- a) 0.5 percent nitrate
- b) 0.8 percent ammonium
- c) 5.75 percent TKN.

In this example the sludge was surface spread, then immediately incorporated:

From above, the mineralization factor for aerobically digested sludge is 0.3 and the ammonia (NH₃) volatilization factor under these conditions is 0.75; therefore,

$$\begin{aligned}\% \text{ PAN} &= \text{nitrate} + \text{ammonia adjusted for volatilization} + \text{organic nitrogen to be mineralized} \\ &= 0.5 + (0.8) (0.75) + (5.75 - 0.5 - 0.8) (0.3) \\ &= 0.5 + 0.6 + (4.45) (0.3)\end{aligned}$$

% PAN = 2.435% or 48.7 pounds per dry ton

3. How Much PAN is Needed?

PAN requirements vary depending on the crop. If the nitrogen recommendation for a crop were 100 pounds nitrogen/acre, then the amount of sludge needed to supply that amount of nitrogen would be 100 pounds nitrogen/48.7 pounds nitrogen per ton or 2.05 tons/acre.

The application rate obtained by this calculation is appropriate for determining the agronomic rate for sludge applications when nitrogen is the rate determining factor.

4. Lime Requirement

For lime stabilized sludge having a high acid neutralizing power, the lime requirement of the soil and the neutralizing power of the sludge determine its application rate.

5. What Farmers and Crop Advisers Need to Know

In most cases sewage sludge or biosolids from wastewater treatment plants will be dealt as other similar agricultural wastes or fertilizer, with a couple of exceptions. The waste generator and waste hauler/applicator are responsible for obtaining the necessary permits and approvals as well as keeping records as required by the regulations. The regulatory and permitting process provides assurance that the waste is suitable for land application and that the methods, including

timing of application and the agronomic rate, are appropriate for the soil/crop conditions that exist. Regarding the timing of applications, the same nutrient management practices used for commercial fertilizers and manure apply to sewage sludge since the same soil and crop management principles and soil processes are involved. Generally, farmers and crop advisers will be more knowledgeable about agronomic and horticultural practices than the waste applicator will be.

6. Records

The waste generator and the waste applicator (the permittee) must keep records on the chemical concentration of waste materials, land used for application, dates of application, and an inventory of metal loading of the soil. These records are vital to successful implementation of the regulations and ensuring that the assumptions made in the risk analyses are applicable. Farmers are not required to maintain such records but we recommend that they maintain copies of the waste analyses data sheets that generators and haulers are required to provide the landowner or operator, as well as records of fields that were treated and the soil-test results.

7. Lime-stabilized Sludge

Lime-stabilized sludge has a significant lime equivalent. Consequently, the application rate must be based on its alkalinity, measured by its calcium carbonate equivalent and the lime requirement of the soil. Lime-stabilized sludge applications are made at three to five year intervals depending on the soil test determined pH and lime requirement. Obviously, soil testing becomes a vital step in scheduling applications. The same will be true for some solid waste materials, such as paper mill wastes and some coal or wood ashes, if they have significant alkalinity.

8. Other Limiting Factors

In some instances, as with poultry litter and other animal wastes, waste management/nutrient management plans limit application rates if soil test phosphorus concentrations become too high. Also, the DHEC guidance manual for land application of sewage sludge, sometimes referred to as "biosolids", indicates that application must cease if loading of nitrate within the upper 4-feet of soil reaches 200 pounds per acre and remains at that level for more than one year.

9. Setbacks

Fertilizer may be applied to the "fence line" without regard to property boundaries, roads, and social concerns. The same is not true for sewage sludge, manure and other wastes. Buffer zones, or setbacks, around property boundaries, roadways, drainage ways, surface waters and residential areas significantly limit land that can be treated.

10. Social Considerations

Social concerns can be major obstacles to effective use of waste materials as crop nutrient element sources, especially if concerns are ignored. Farmers and crop advisers will probably not become involved in estimating application rates or permitting. However, as agricultural leaders in the community, they may receive questions from other farmers, neighbors of farmers who utilize sewage sludge, concerned citizens, county council members, and even those directly involved in the permitting and regulatory process, such as wastewater treatment plant engineers and commercial applicators. Each individual may be viewing the issue from a different perspective and have substantial misinformation. Our purpose here is to provide some

background information to help farmers and crop advisers respond to these concerns. Be aware of the degree of environmental and health protection provided by the regulatory and permitting process and use this information to correct misunderstandings about the land application of sewage sludge and other waste materials.

Land application is a preferred way to deal with many waste materials. It is preferred to placement in a land-fill, incineration or some other disposal method that fails to capture the beneficial value and which may lead to unnecessary pollution of soil, air or water. The regulations that have been developed protect health and the environment. If the regulations are followed there should be no problem. If the regulations are not followed, the consequences may range from annoyance and negative publicity to shutting down land application programs.

11. Waste Management for Forest Areas

Land areas under forest or woodlands are not normally fertilized like other agronomic or horticultural crops. However, these sites offer opportunity to land-apply and recycle organic and inorganic waste materials on a large scale. In so doing, productivity of forest products can be increased. Waste materials, including poultry, dairy, organic, biosolids, domestic, and industrial, can be applied to the forest lands, based on sound management practices that meet environmental regulations.

Application periods and quantities vary based on the types of soil and trees and the annual cycle of temperature and moisture. Application schedules should be based on the nutritional needs of the tree types, soil pH, constituent analysis of the waste materials, metal loading capacities of the soil and equipment accessibility for spreading the material. Sufficient tree-spacing may be considered if newly establishing a forest land for facilitating future waste recycling efforts. Soil type should be considered because of potential leaching of nitrogen or other contaminants. Landscape factors like slope are also important for erosion control. Generally, applications can be made year-round for pine trees, but for hardwoods, applications should be restricted to the warm periods between February and October.

The following soil pH ranges are recommended:

| Type of Trees | Soil pH Range |
|-------------------------|----------------------|
| Pine trees | 5.0 – 6.5 |
| Hardwood or other trees | 5.8 – 6.5 |

Applications are preferred on sites with 5 to 10 years of stand establishment, with trees growing vigorously and ready to close at the crown level. This will ensure maximum nutrient element uptake by the plants. It is recommended that 80% of the forest floor be covered with greater than 1/2 inch of leaf litter to reduce runoff and erosion potential. Depth to seasonal high water should be considered, as is done in the case of agricultural sites. Periods of excessive soil moisture should be avoided to prevent soil compaction.

An effective monitoring plan should be developed based on crop needs and landowner management objectives. This is very important in order to ensure compliance with all the environmental regulations. For further help, contact your local Extension Agent or Faculty in the

Department of Forestry and Natural Resources or Entomology, Soils and Plant Sciences at Clemson University.

12. Summary

- Metals, pathogens, and vector attraction reduction will not be problems if regulations are followed.
- Keep records of waste analyses, soil test data, and dates and amounts of applications.

The waste applicator must request that the soils be analyzed for metal content before an application is made if repeated applications are planned. This will provide documentation of the initial soil concentrations and will be useful for diagnostic purposes should problems arise.

13. References and Documentation

A Plain English Guide to the EPA Part 503 Biosolids Rule. EPN832/R-93/003. September 1994. U.S. Environmental Protection Agency. Washington, DC.

Beneficial Use of Wastewater Biosolids. South Carolina Department of Health & Environmental Control and Clemson University. February 1996.

40 Code of Federal Regulations, Part 503B, *Standards for the Use or Disposal of Sewage Sludge*. Federal Register Volume 58, No. 32, Friday, February 19, 1993. Available from the National Technical Information Service.

SC DHEC South Carolina Regulation 61-107. *Solid Waste Management: Land Application of Solid Waste*. July 26, 1996.

Solid Waste Policy and Management Act of 1991. S. C. Code 4-96-10. Available from DHEC.

SC DHEC South Carolina Regulation 61-43, *Standards for the Permitting of Agricultural Animal Facilities*

State regulations relating to animal waste and other wastes can be viewed, and in many cases downloaded, from the DHEC water website, accessed from the agency's Environmental Home Page: <http://www.scdhec.net/>