MARYLAND COOPERATIVE EXTENSION
UNIVERSITY OF MARYLAND
COLLEGE PARK-EASTERN SHORE

Fact Sheet

Fact Sheet 336

Guidelines for Application of Digested Sewage Sludge and Composted Sewage Sludge to Agricultural Land

Introduction

In states such as Maryland that have a rapidly increasing population and a relatively small land area, the effects of a growing population are threatening water and air quality. This is especially true when rapidly urbanizing areas concentrate near streams and rivers, lakes, or coastlines of the Chesapeake Bay and the Atlantic Ocean. One effect of a growing population is the need to safely treat increasing volumes of wastewater and dispose of the semisolid sewage sludge the treatment produces.

The application of the best available technology to protect Maryland's environmental resources is a major commitment of the "Agreement for the Continued Restoration of the Chesapeake Bay," signed by the Governors of Maryland, Pennsylvania and Virginia and the Mayor of the District of Columbia. However, as more effective wastewater treatment processes are used, greater quantities of sludge will be generated and require disposal. Safe disposal of the massive amounts of sewage sludge produced in today's society presents a major problem in environmental management.

This fact sheet presents guidelines for the optimum agronomic utilization of wastewater sludge on agricultural lands. Guidelines for the use of sludge in the production of ornamental and floricultural crops, orchards, nurseries, and home gardens are available in a companion Fact Sheet.

What Is Sludge?

Sludge is an inevitable byproduct of wastewater treatment that is produced in sewage treatment plants as organic material and nutrients (nitrogen and phosphorus) are removed from the wastewater before releasing the treated water back into the environment (streams or rivers). Sludge is a thick mixture of bacteria and other microorganisms, organic and inorganic material, nutrients and heavy solids that settles from wastewater during treatment.

Sludge has a physical and chemical composition that varies greatly depending on the industries and communities served by the sewage treatment system and by the type of treatment system. Sludge from systems that receive wastewater primarily from residential areas usually contains much lower levels of heavy metals than does sludge from areas where there are industrial users. However, sludge also contains several components potentially useful as soil additives. Maryland sewage sludge typically contains from less than 1 percent to more than 10 percent nitrogen (N) on a dry weight basis; 2 to 7 percent is common. Phosphate (P_2O_5) contents range from less than 1 percent to more than 14 percent; 3 to 8 percent is

common. Nitrogen and phosphorus are valuable as plant nutrients. The organic matter in sludge also is particularly useful as a soil additive.

Sludge Types

Primary sludge is composed of the solids (mostly remains of food and fecal matter) and microorganisms that settle from wastewater during the initial stages of treatment. In some treatment facilities, lime may be added at this stage of treatment.

Activated sludge accumulates during more advanced stages of sewage treatment. This sludge consists mainly of the bodies of bacteria that have been feeding on the soluble and suspended organic material in the sewage.

Digested sludge is formed when mixtures of primary and activated sludge are combined and further processed in tanks with or without oxygen to kill disease-producing organisms. Digested sludge is a stabilized material that can be applied to agricultural land and is the most common type produced in the United States. It still contains a relatively high percentage of water.

Composted sludge is made by combining either digested or undigested dewatered sludge with wood chips or other bulking agents under carefully controlled conditions. With the proper amount of air and moisture, microorganisms convert the sludge into a composted product that has little odor and is relatively free of pathogenic microorganisms. Composted sludge makes a good soil conditioner.

What Options Exist for Sludge Disposal?

In the past, sludge was disposed of in a number of ways that are no longer acceptable. The two most common techniques of sludge disposal in the United States have been land application and incineration. Both methods have potential drawbacks. Landfills can no longer be used. Land and management costs of landfills are very high, and there often is a risk of materials in landfills contaminating both surface and ground water. Suitable disposal areas near cities have become more and more difficult to locate. Many citizens strongly object to disposal sites close to residential areas and to transporting sludge through or past their communities. Ocean dumping has been a solution for some coastal communities, but no longer can be used because of negative environmental impacts. Incineration requires a large capital investment and requires expensive safeguards against atmospheric pollution. Incineration uses large amounts of fuel and produces a concentrated and sometimes toxic end product (residual ash) that has no nutrient or organic value as a soil additive and often is more difficult to dispose of than the original sludge.

The application of sludge to agricultural land presents a partial solution to the problem. It offers farmers some economic advantages by providing organic matter and nutrients that can partially replace fertilizer for some crops. The limits on the amounts of sludge that should be applied are controlled by two factors: 1) the nutrient requirements of the crop being grown, which should not be exceeded to avoid polluting surface and ground waters, and 2) the need to keep the accumulated amounts of heavy metals below the total that is safe for a particular soil. The last restriction is particularly important. If the amounts accumulated become too high, the soil may be permanently and irreversibly damaged for growing crops to be eaten by humans or animals. Regulations and application guidelines have been developed to make sludge disposal as environmentally acceptable as possible, while at the same time protective of human health.

Regulations

Legal regulations governing land application of sewage sludge in Maryland were established in 1986 by the Department of Health and Mental Hygiene under the authority of the Health-Environmental Articles 9-230 through 9-249 and 9-269 through 9-270 of the Annotated Code of Maryland. The regulations are administered by the Maryland Department of the Environment.

The regulations require the issuance of permits for land application of sludge within the state and also define the maximum permissible application rates and amounts of heavy metals that may be allowed to accumulate in various types of soil. The regulations also include detailed specifications on the timing and distribution of sludge applications. Since July 1, 1989, a permanent record of sludge applications to agricultural land must be maintained at each local county soil conservation district office. Further details about these regulations may be found in the Maryland Cooperative Extension Fact Sheet 439, "Using Sewage Sludge on Farmland."

The University of Maryland endorses the state regulations as statements of the maximum amounts of sludge that may be safely used while protecting the quality of the environment and the health of the people in the state. Any differences between statements and guidelines contained in this fact sheet and the state regulations reflect the advisory nature of this document. The recommendations presented here take into account several factors that are not emphasized in the regulations, which principally are concerned with setting the limits for protecting the environment.

The guidelines presented in this fact sheet represent the considered judgment of the technical and scientific faculty of the University of Maryland on the way that digested or composted sewage sludge should be used on agricultural soils in the state. These guidelines are based on our present knowledge of the agronomic and environmental effects of sludge used for this purpose. However, it must be recognized that increased loadings of heavy metals and long-lasting organic chemicals may have long-term effects on soils that we do not yet understand.

In the light of these limitations to our knowledge, the University of Maryland recognizes that it is not possible to predict with complete certainty the possible long-term environmental and health effects of applications of sewage sludge, and the University does not, therefore, accept responsibility for future effects that are due to causes that are unknown at this time.

Recommendations

1. The annual rate of sludge application to farmland should be determined according to the nitrogen requirement of the crop. For digested sludge, this rate is based on the content of inorganic nitrogen plus 20 percent of the organic nitrogen for anaerobically or chemically stabilized sludge, and 40 percent of the organic nitrogen for aerobically digested sludge. In the case of sewage sludge

Table 1. Maximum cumulative sludge metal applications for farmland.

Metal	Textural classes		
	Loamy sand, sandy loam	Fine sandy loam, very fine sandy loam, loam, silt loam	Silt, clay loam, sandy clay loam, silty clay loam, sandy clay, silty clay, clay
	Pounds per acre		
Cd	2.0	3.0	4.5
Zn	50.0	150.0	300.0
Cu	25.0	75.0	150.0
Ni	10.0	30.0	60.0
Pb	100.0	300.0	600.0
Cr	100.0	300.0	600.0

If the percentage of coarse fragments is greater than 15 percent by volume, the recommended loading rate should be lowered by an appropriate amount. As a first approximation, the loading rate could be reduced by the estimated percentage of coarse fragments.

compost, it is estimated that 10 percent of the organic nitrogen is available to the crop.

2. The maximum amounts of sludge-borne metals that may be applied to farmland are given in Table 1.

3. The annual cadmium loading rate should not exceed 0.4 pounds per acre.

4. Sludge that contains more than the amounts of the following materials on a dry weight basis should not be applied to farmland.

Zinc (Zn	2,500 ppm
Copper (Cu)	1,000 ppm
Nickel (Ni)	200 ppm
Cadmium (Cd)	25 ppm
Lead (Pb)	1,000 ppm
Mercury (Hg)	10 ppm
Chromium (Cr)	1,000 ppm
PCB's	10 ppm

5. Soil pH should be adjusted to between 6.5 and 7.0 when sludge is applied and should be maintained at 6.0 or above as long as the land is used for production of crops for human or animal consumption.

6. On pastures or hay crops, sludge should be applied immediately after hay harvest or close grazing. The fields should not be harvested or grazed for at least 30 days after application. Application is also recommended in the spring after soils have thawed but before significant growth has occurred.

7. Sludge must not be used on land where tobacco is to be grown.

8. Do not apply sludge on soils where the bedrock is less than 24 inches deep. Applications should be confined to well-drained and moderately well-drained soils with at least 24 inches depth to the seasonal high water table, and where surface slopes do not exceed 15 percent unless surface structures are used to control runoff and erosion.

9. Sludge should not be applied to soils that test "very high" in available soil phosphate. Continued applications of sludge over several years may result in the accumulation of very high levels of total phosphate in topsoil. Under some circumstances, this may induce imbalances of some minor elements. Surface runoff or sediment from such soils also may deliver unacceptably high concentrations of phosphates to surface waters.

10. Do not apply sewage sludge in any form to commercial vegetable crops. Unless the levels of heavy metals in both the sludge and in the soil are known and unless the soil pH is controlled carefully, there are possible risks to human health from the ingestion of vegetables containing excessive cadmium. Some leafy vegetables tend to accumulate large amounts of this metal.

Application of Sludge to Legume Crops

Legumes fix their own nitrogen; thus, application of sewage sludge to land used for growing legumes is a poor use of a valuable resource. Preliminary evidence indicates that sewage sludge may initially depress legume yields for a period of 1 year following the application of sludge to land. The high soluble salt content of the sludge is believed to be responsible for this observation. Once the salts are leached from the soil, the remaining micronutrients and improved soil physical properties enhance legume growth. Further data, however, is required to confirm initial observations. Applications of sludge to perennial legumes, such as alfalfa, may also make it more difficult to control weeds, especially if excess nitrogen is added to the soil. The excess sludge-nitrogen, if added at the wrong time of the year, may increase weed germination and the subsequent growth of annual weed grasses.

Determining Application Rates of Sewage Sludge

Maryland Cooperative Extension will provide, on request, specific recommendations for the use of sewage sludge based on crop nutrient requirements, projected yields, soil conditions, and cumulative heavy metal loadings for the particular soil. These recommendations require the results of a soil test (see Soil Analysis below) and the results of an analysis of the particular sludge to be used from the Maryland Department of Agriculture State Chemist. In the absence of an analysis

of the particular sludge, which should be available from the application contractor, recommendations can be made using data on the average composition of other sludge samples recently available from the same source.

Available Nitrogen in Sludge

Nitrogen loading is one of the principal criteria for establishing an annual application rate for a particular sludge on a specific soil. The nitrogen requirement of the crop and the available nitrogen are used to determine this application rate where it is not controlled by the limitations of the heavy metal application (see Recommendation 1.) The amount of nitrogen that is available to the crop during the first growing year from various types of sludge is estimated as follows:

Sludge type	Plant available nitrogen
Aerobically digested Lime stabilized Unstabilized primary Waste activated	Inorganic N + 40% of the organic N
Anaerobically digested Chemically stabilized	Inorganic N + 20% of the organic N
Sewage sludge compost	Inorganic N + 10% of the organic N

To estimate the available residual nitrogen in the soil from sludge applied in previous years, it is assumed that the decay rate of the organic nitrogen in all types of sludge decreases by 50 percent each year during the first 3 years following the year of application. For instance, for aerobically digested sludge, the amount of plant available nitrogen during the first cropping season after application would be estimated as above. For the second, third and fourth seasons after application, the plant available nitrogen released would be estimated by determining 20 percent, 10 percent and 5 percent, respectively, of the remaining organic nitrogen.

Soil Analysis

Instructions and containers for submitting samples for analysis can be obtained from a regional soil testing lab. See http://www.agnr.umd.edu/SoilTesting/ for a list of regional soil testing labs.

Sewage Sludge Analysis

The analysis of the sewage sludge must include total nitrogen, ammonium nitrogen, phosphate, potash, calcium, magnesium, manganese, iron, chromium, zinc, copper, nickel, cadmium, lead, and mercury with the percentage of total solids and pH. The State Chemist may be reached through the Maryland State Department of Agriculture, 50 Harry S. Truman Parkway, Annapolis, Maryland 21401.

Sludge Application Methods

Sludge must be stabilized before land application to reduce public health hazards and to prevent objectionable odors and nuisance conditions. Liquid digested sludge may be applied to the land by using a spreading method such as a tank truck, liquid manure spreader, or subsurface injection in the plow layer. Dried or dewatered stabilized sludge or composted material from digested sludge can be spread with a manure spreader.

It is very important that sludge be applied uniformly over the field so that recommended application rates are not exceeded. Dumping sludge in piles in the field and then spreading it is not an acceptable practice.

Economics of Land Application of Sewage Sludge

The principal economic benefit from the use of sewage sludge application lies in the reduction of fertilizer needs because of the nutrients added in the sludge. The immediate benefits most often result from savings in the cost of nitrogen. In particular cases, the savings depend on the projected yield goal, the sludge application rate, and the reduction in fertilizer costs (including the time and cost of application). An estimate of the value of a sludge application can be obtained using a computerized examination of the

range of options available from your county Extension office.

Long-term benefits may accrue from the accumulation of increased levels of soil phosphate. This may happen because the amount of phosphorus in most sludge is high in proportion to the nitrogen, so if sludge applications that completely replace fertilizer nitrogen are continued over a long period, soil phosphate will steadily increase. In contrast, the low potassium content of most sludge may lead to the depletion of this nutrient, particularly in sandy soils. Therefore, the short-term economic advantages sometimes may be offset by costs that may be needed to adjust the nutrient balances at a later time. The possible costs of future lime applications that may be needed to maintain pH levels above 6.0 required for the issuance of a permit to apply sludge on agricultural land should be evaluated also.

Potential economic disadvantages may arise from the permanent increase in heavy metal content of the soil associated with repeated sludge use. Such increases may limit the market value of future forages and vegetables produced on sludge-treated land. The possibility of this occurrence should be taken into account in making any decisions concerning sewage sludge applications to land.

Projections of the effects that repeated land applications of sludge and animal waste in various cropping sequences have on the reserves of soil nutrients are available through county Cooperative Extension agents. These estimates are based on computerized calculations of the long-term balances between the amounts of nutrients removed by the crops and those added in the sludge or fertilizer.

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