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Sludge and the Land: The Role of Soil and Water Conservation Districts in Land Application of Sewage Sludge

Final Report

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Foreword

This paper has been prepared by the staff of the National Association of Conservation Districts as a contribution toward clarifying the potential role of conservation districts in land application of sewage sludge. We are indebted to the many people who assisted in its writing and review.

The initial data and materials for the study were assembled and the paper was written by W. Wendell Fletcher.

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These people all contributed to the amount and the quality of the material in the paper, but NACD is responsible for the conclusions reached and for any errors that may become evident.

Neil Sampson
Executive Vice President

Introduction

As part of the country's commitment to reducing water pollution, many communities either are building municipal wastewater treatment plants for the first time, or are upgrading existing treatment facilities. While the new facilities reduce quantities of pollutants entering lakes and streams, they also produce large amounts of residue (called sewage sludge) which is left behind after the wastewater is processed and reused or discharged into the waterbody. The sludge consists of organic matter, nutrients, and other materials (such as heavy metal contaminants) that are removed from the wastewater during treatment.

In the past, disposal of sludge received relatively little attention on the part of water pollution control officials. But, as more and more sewage treatment plants come into operation, the sheer volume of sludge is increasing more rapidly. By 1990, according to one projection, as much as 16 million tons of dry sewage sludge will be produced each year—nearly three times the amount of sludge produced annually in the 1970s. Further complicating the situation is the fact that many of the traditional methods of sludge disposal—such as ocean dumping, placement of sludge in sanitary landfills, or incineration—have become environmentally or politically unacceptable, or are simply too expensive for many communities to afford.

As a consequence, there is an upsurge of interest in **land application** of sludge. Employed for decades by many communites in the mid-West, the technique makes an asset out of what otherwise is a problem: it turns a waste into a valuable resource by using the land to recyle the organic matter and nutrients that the sludge contains. When properly applied to the land, the sludge conditions the soil and serves as a fertilizer supplement that can be put to beneficial use in agriculture, forestry, land reclamation, and other land management activities.

Examples of land application opportunities include:

— spreading sludge on cropland, pasture or grassland;

— using the sludge to help reclaim surface mined land, mine spoils, and other drastically disturbed lands.

— application of sludge products on gardens, nurseries, golf courses, etc.

— application of sludge on forestland, parkland or highway median strips.

A key advantage of land application is that it usually takes place on privately owned land. Thus, the municipality can avoid the high costs of acquiring land for disposal sites, or of constructing expensive sludge processing facilities. Private land owners who accept the sludge not only help to solve a municipal problem, but also may improve the condition of the soil, reduce fertilizer costs and increase crop yields.

Sludge application to land is not problem free, however. A number of factors can limit its use. For the farmer, the most important of these is the quality of the sludge itself. All sludge contains at least small concentrations of heavy metals and other potentially toxic contaminants that may enter municipal wastewater treatment systems from households, industries or storm drains. In so-called "good" or "clean" sludges, contaminants are present at such low concentrations that they do not pose an appreciable hazard for contamination of the soil, vegetation, or surface and underground water supplies. Sludges that contain higher concentrations of heavy metals or other contaminants are usually not appropriate for most land application techniques unless special management procedures are followed that carefully limit the locations where and amount of these materials that are applied to the land.

As increasing numbers of communities around the country upgrade wastewater treatment facilities, the issue of sludge management will be increasingly visible. Recycling sewage sludge on private land will not always be a viable option for a given community, but where it is, the active involvement of farmers and other landowners from the earliest stages will be essential. All too often, land application proposals have failed because good channels of communication between municipal officials, landowners and nearby residents were not established.

Moreover, in many cases, a land application program will not be carried out in the urban area where most of the sludge is produced, but in neighboring rural jurisdictions. If the land application program is to succeed the urban jurisdiction needs to be especially sensitive to the special problems and concerns of the rural area residents.

This booklet is aimed at facilitating communication between rural and urban areas in assessing sewage sludge management options involving land application. The booklet briefly describes alternative beneficial uses for sludge; alternative roles for soil and water conservation districts in land application of sludge; the difference between a "good" and "bad" sludge for land application; factors involved in designing a sludge application program for agricultural land; and case histories of involvement of agricultural agencies in land application.

Because the actual design of a land application program is a highly technical site specific matter, the booklet is not intended to provide specific technical guidance to individual communities to their potential land application projects. A variety of information sources and state and local agencies can provide such technical assistance.

Beneficial Uses of Sludge

Currently, about one-fourth of all sewage sludge is applied to the land through a variety of recycling approaches. About one fifth of all municipal sewage plants "dispose" of at least part of their sludge through land application.

Although expected to increase rapidly in the years to come, land application is not always a viable disposal option for an individual community even when the quality of the sludge is appropriate for land application. Some communities may not have suitable land available close enough to the treatment plant to make transporting of sludge to farmland practical. Still other communities may encounter resistance on the part of residents located near land application sites. Yet for many communities, recycling sludge on the land may be the most cost-effective and environmentally sound way to dispose of their sludge.

Many of the advanced engineering technologies for disposing of sludge are expensive to build and both labor and energy intensive—and are thus subject to increasing operation costs as energy and labor prices continue to rise. The costs to the municipality of land application vary from place to place, depending primarily on such factors as the distance of the application site from the treatment plant, and the quantity of sludge that is produced. But, for many small communities and even some large cities, land application has proven to be less costly than other sludge disposal systems.

Environmental concerns have already resulted in the phasing out of many coastal cities' use of ocean dumping as a sludge disposal alternative. In other areas, air quality limitations along with increasing energy costs have precluded incineration. Another disposal option—the sanitary landfill—generally prompts more vehement political opposition from nearby residents than does land application. Because landfills involve disposal of large quantities of wastes on a small land area, there are often major concerns about odors, groundwater contamination and runoff of pollutants to nearby streams. (Improper land application can also result in similar problems, but because smaller quantities of sludge are applied per acre, the potential for such problems is seldom so great.)

Thus, where economics and the quality of the sludge permits, land application may be the most suitable disposal technique—especially since it affords the opportunity to recyle resources which would be otherwise wasted. This is an important philosophical concept in a society that has only recently discovered that its natural resources are limited. But it also has tangible results—as many farmers, mine owners, and land managing agencies are discovering—in terms of improved productivity of the soil. As a result, many communities do not have to acquire land to dispose of their sludge; many private landowners are more than willing to accept it.

Briefly discussed below are the major recycling alternatives:

Land Spreading on Cropland, Range or Pasture

Spreading of sludge on cropland or other farmland is the most common method of land application. This approach has been used for decades by some communities—especially in the mid-Western part of the country where suitable cropland is widely available and population densities are relatively low. An estimated 400 towns in Illinois and 250 towns in Ohio alone apply sludge to the land. As understanding has grown that a properly managed land application program will bring benefits to farmers, the interest on the part of the farmers in sludge application is growing in other areas of the country.

One of the key benefits to the farmer is economics. As an incentive for land application, most municipalities will provide sludge to farmers at little or no cost. Thus, land spreading of good quality sludge can reduce the fertilizer costs of participating farmers. According to the Council on Agricultural Science and Technology, a dry metric ton of sewage sludge contains $15 to $30 worth of nutrients, based on 1976 fertilizer prices. It is estimated that the fertilizer replacement value of N, P, and K nutrients in all domestically produced sewage sludge is nearly $200 million per year.

Ongoing research designed to test crop yields on sludge-amended land is being conducted in several areas of the country. Researchers in Ohio, for example, found that, over a three year period, corn and wheat yields on test plots amended with three to six tons of sludge per acre were roughly comparable to yields on test plots where commercial fertilizer was utilized at recommended application rates, and substantially above the control plots where no fertilizer or sludge was applied. Similar research in Oregon, Wisconsin, Maryland, Alabama, and elsewhere shows that sludge increases crop yields when properly applied.

Farmers participating in landspreading should be certain that the sludge provided by the municipality is of good quality for agricultural use. Application rates for high quality sludges are normally determined on the basis of nitrogen or in some cases phosphorus levels in the sludge. Where lesser quality sludge with higher levels of heavy metals or toxic organic compounds are involved, smaller or less frequent applications may be necessary to adequately limit the amounts of contaminants applied with the sludge.

Special management criteria—both federal and state—may affect farm management practices on crop or pasture land for some time after sludge application. These can include: limitations on the kinds of crops grown, restrictions on the quantity and timing of sludge application in order to reduce levels of pathogens or heavy metal contaminants in crops or animals subsequently consumed by humans, and periodic liming of the soil in order to reduce the solubility of heavy metals.

Although some special managment practices are needed, a well designed land spreading operation generally can be undertaken in such a way as to provide minimal interference with normal farm activities. Agricultural agencies, such as local conservation districts and agricultural extension services, can play a key role in helping to mesh municipal and landowner objectives in land application of sewage sludge.

Forest Land Application

Although not yet widely utilized in this country, application of sewage sludge to forest land may avoid some of the potential hazards and public concerns that sometimes arise in the landspreading of sludge on cropland. While there may be some biomagnification of contaminants in wildlife, concern about build-up of heavy metals in the human food chain is largely avoided. (Nonetheless, some regulatory agencies recommend that the same criteria be used in determining acceptable levels of heavy metals in sludge applied to forest land that are used in agricultural land spreading. Reasons for this include limited data about impacts of heavy metals on the forest ecosystem; possible future clearing of sludge-amended forest land for subsequent use in agricultural production; and the prevalent acidity of forest soils, which encourages solubility of metals.)

Because forest land is generally located at some distance from thickly settled areas,

concern about excessive odors from improper sludge disposal practices is unlikely. Moreover, much of the forest acreage in the United States—especially in the West—is deficient in nitrogen. Sludge application can be a cheap and convenient way to improve forest production. On intensively managed stands, forest land application of sludge is likely to result in fewer interruptions in management practices than is the case with row crop production. In areas with cold weather, however, sludge application is generally avoided in the late summer and early fall in order to prevent rapid twig growth and possible subsequent damage from freezing weather.

Reclamation of Surface Mined Land and Other Disturbed Lands

In several areas around the country, sewage sludge is being applied to surface mined land and other drastically disturbed land areas as an aid to reclamation. Experiments in the eastern United States and elsewhere have shown that use of sludge can assist in the revegetation of such disturbed areas by conditioning the soil and promoting plant growth. Because of the acidic nature of surface mine spoils, careful management and monitoring is needed to help minimize solubility of heavy metals in the soil or in runoff.

Surface mine reclamation has become a key sludge disposal alternative for some large cities which produce large volumes of sludge. Such sludges often contain higher levels of heavy metals or other wastes from industry than would be appropriate for land application at higher application rates to agricultural land. Less stringent application rate restrictions are usually imposed on sludge used in mine reclamation. Moreover, because the volume of sludge from large cities is so great, and because repeated application on the surface mined land may be permitted, economics of scale may permit transportation of the sludge to distant surface mine sites.

For over 10 years, Chicago has been barging much of its sludge over 200 miles down the Illinois River to Fulton County, Illinois, where the city has acquired several thousand acres of previously mined land for land application. More recently, the City of Philadelphia has begun a land application program involving shipment of sludge (by backhaul in coal trucks) some 250 miles for use in reclaiming surface mined land in Somerset County, PA. Research and monitoring is now being conducted to determine any potential problems associated with using sludge-reclaimed land for agriculture once reclamation is achieved.

Marketing Sludge Products

Although liquid sludge is often preferred by farmers because it is easy to apply, a number of communities around the country (as well as several private firms) now market sludge products for use by commercial nurseries and horticulturalists, turf farmers, gardeners, golf courses, and other users. Several commercially available products—ranging from products wholly comprised of processed sludge, to sludge based composts augmented by other materials—are now available.

The City of Milwaukee's sludge product, Milorganite, has been marketed for decades. The sludge is heat dried to reduce moisture, destroy pathogens, and granulated. The sludge is then packaged and sold for use as a fertilizer on golf courses, and other uses where nonedible plants are involved.

More recently, composting of sludge (which maintains the soil conditioning capabilities of the organic matter in the sludge) has become the subject of widespread interest. Although a number of different composting methods have been

Other Sewage Sludge Disposal Processes

In addition to recycling of sludge, several other major sludge disposal practices are employed, including:

Landfilling—about 25 percent of all sludge is disposed of in sanitary landfills. Such facilities—where large volumes of sludge are disposed of on relatively small land areas—generally produce vehement political opposition. This may delay or complicate municipal sludge disposal plans. Public concerns about odors, possible health hazards and contamination of groundwater or surface waters due to leaching are more prevalent in the case of landfilling than land application because of the far greater volume of sludges and other wastes that are disposed of in one location.

Good management of sanitary landfills generally requires stabilization of the sludge, covering of the sludge each day with soil and other precautionary measures to prevent odors and control over other nuisance problems—depending on the extent of public access to the site. The selection of the site itself should take into account the need to prevent groundwater contamination, and runoff of materials into surface waters, as well as nearby and abutting land uses which might be affected by the landfill.

Careful monitoring of groundwater (through observation wells) and surface water quality is essential in landfill operations.

Incineration—in instances where land availability is limited, and the volume of sludge is large, incineration is sometimes used to reduce the volume of sludge to more manageable proportions. It is not an ultimate disposal method, however, since the ash remaining after incineration must be disposed of eventually. Air quality concerns can limit the circumstances in which incineration can be used. Because incineration is an energy intensive process, recovery and reuse of energy from the incineration process itself is often essential to keep down costs. A number of different processes and technologies have been developed to help reduce energy costs associated with incineration.

Ocean Disposal—although long used by many large coastal cities, disposal of sludge in the ocean has been phased out by many cities in recent years, mostly because of environmental concerns. Since the mid-1970s, ocean dumping has been permitted only through the issuance of temporary permits. Most communities utilizing this method of disposal have been actively devising other means of sludge disposal.

Lagoons and Storage Basins—many communities simply dispose of their sludge in lagoons. Sometimes lagoons are used to stabilize sludge prior to land application or to store sludge during those periods when land application is inappropriate. Key problems with lagoons include: odors associated with inadequate management, public opposition from nearby landowners, and site limitations associated with possible groundwater contamination. Nonetheless, lagoons and storage basins are often a cheap and convenient method for treating sludge.

developed, all composting techniques stabilize the sludge through microbial decomposition. While the decomposition process may reduce nitrogen concentrations in the sludge, the end product is useful as a soil conditioner and low analysis fertilizer.

The "aerated pile" method of composting, developed by researchers from the U.S. Department of Agriculture and the Maryland Environmental Service Corp., is receiving especially widespread attention, since it can be used to compost both small and large quantities of either digested or undigested sludges in a relatively short period of time. The process involves mixing the sludge with a bulking agent (such as woodchips) to increase aeration. The mixture is then placed in carefully constructed piles for several weeks time, during which stabilization and curing takes place.

Some private firms add extra ingredients to composted sludge, and market the product commercially. One of these sludge based products, for example, includes animal blood, bone meal, sawdust, shredded bark and granite dust in addition to the sludge. According to one firm, use of their product results in improvements in crop yields, and better soil conditions than commercial fertilizer. Heavy metal concentrations are reported to be well within the guidelines established for food chain crops.

Generally speaking, composted sludge has a minimal potential for causing odor problems, and is easy to store. Composting reduces levels of persistent organic compounds and pathogens. Composting of sewage sludge is also considered an alternative technology under the Clean Water Act, and is eligible for up to 85 percent federal construction grants for land, equipment and related construction costs.

Recycling Wastes in Natural Biological Systems

Currently, considerable research is being conducted on the potential of other natural biological systems (such as wetlands, ponds, and other aquatic systems) in treatment of municipal wastewater. Utilization of sludge in such processes is more limited, due to concerns about biomagnification of contaminants. However, as more research is conducted, some sludge disposal processes may come to involve these other natural biological systems. Any such approach will require careful management to prevent damage to natural ecosystems.

Conservation Districts and Land Application of Sludge

Soil and water conservation districts are local units of state government, which work with federal, state and local agencies, and individual landowners to implement appropriate conservation programs. Since the mid-1930s, nearly 3,000 conservation districts have been established. They cover more than 99 percent of the nation, and are generally (but not always) contiguous with county boundaries.

Districts are directed by local citizens representing a variety of occupations associated with resource management. Nationwide, over 17,000 local citizens serve as district directors. From an initial focus on soil and water conservation, district activities have expanded over the years to include such additional areas of concern as nonpoint water pollution, coastal zone management, surface mine reclamation, wetlands protection, and a variety of other resource management concerns and objectives.

A major component of every conservation district's program is the assistance it provides to individual landowners. At the request of the owner, the conservation district undertakes a cooperative effort with the landowner to develop conservation plans intended to achieve resource conservation objectives as well as the individual owner's objectives. Responsibility for implementing the conservation plan rests with the landowner, but additional technical assistance on a continuing basis will be provided by the district when requested. A variety of federal and state cost-sharing programs also have been established to help landowners implement such plans.

Because the conservation district works closely with both individual landowners and other units of government, it is often able to facilitate interaction and to remedy problems that might arise when different objectives are apparent. This is an especially important consideration in the land application of sewage sludge, which, in many instances, is applied to privately owned land. Many of the successful sludge application programs conducted in this country have involved the intensive participation of the local conservation district.

Discussed below are some alternative roles that conservation districts and other agricultural organizations can play in helping to assure that land application of sludge is conducted in the most beneficial way.

Objectives of Agricultural Involvement in Land Application:

When done properly, land application projects have multiple benefits to the public at large, to individuals landowners, and to the objectives of resource conservation. Although the circumstances in each commu-

National Association of Conservation Districts' Policy Position on Sludge

As more communities assess land application options, making sure that a program is sensibile not only for the community but also for the landowner is a pressing priority. In 1980 and 1981, the conservation districts—through their national association—voted to adopt policies encouraging research and implementation of safe and effective methods for recycling sewage sludge. In addition, several state associations of conservation districts have adopted policies on sewage sludge and land application.

The 1981 policy statement follows:

1. With increasingly strict restrictions on the dumping of sewage sludge in the oceans, increased attention needs to be given to its safe disposal on land. In addition to organic matter and plant nutrients, sludge can contain both beneficial and harmful microorganisms, heavy metals and organic chemicals from both industrial and urban runoff.

2. NACD urges both USDA and EPA to improve their capability to help local communities deal with appropriate disposal of sewage sludge. In addition to accelerated research into the problems of sludge disposal on agricultural land, there needs to be a way to assist communities in locating disposal sites and developing management plans.

3. State Associations of districts should work with state governments to assure that state policies and guidelines for sludge application on agricultural land consider sound agricultural and conservation practices. State monitoring programs should be established to assure that all sludge applied to farmland has been properly tested and its safety to crops and soils assured.

nity will differ, the objectives of conservation districts in land application projects may include such items as the following:

— Helping to assure that the quality of the sludge is appropriate for land application, and that proper management techniques are utilized in applying the sludge to the land.

— Helping to safeguard the interests of the farmer or other landowner in land application.

— Furthering conservation objectives such as rehabilitation of drastically disturbed land, recycling of resources, and improving crop yields and soil conditions.

— Improving relations between urban and rural communities, and increasing public understanding of the role that the land can play in helping to solve urban problems.

— Reducing, in may cases, the economic costs and/or environmental problems associated with some other sludge disposal methods.

— Furthering the national policy goal of conservation districts to achieve safe and effective ways of disposing of sludge.

How to Seek Involvement

In many past instances, municipalities have presented land application strategies to the public with little forewarning. The result can lead to the end of a project before it begins. In other instances, landowners and farmers have approached local wastewater treatment officials to inquire about land application, only to receive a deaf ear.

Conservation districts—representing as they do both local land users and government—often are in an ideal position to get the ball rolling in assessing land application options. Steps that could be taken include:

— Letting local government officials know that land application of sludge, when managed properly, is often less costly and less environmentally objectionable than many other treatment options.

— Informing state and local wastewater officials about district capabilities, resources and interests in land application techniques.

— Offering to coordinate the effort to determine whether land application of sludge is an advisable treatment option on private land for the community.

— Canvassing local farmers and other land users to determine their interest in land application of sludge.

— Beginning to assemble information about land application projects conducted under similar conditions in other communities.

— Being alert and responsible to the concerns of farmers and other local residents about the possible adverse effects of land application projects.

— Initiating or coordinating demonstration tours or educational programs about land application projects in the vicinity.

Specific Aspects of District Involvement

a) Determining whether land application is appropriate:

— Making sure that proper testing has been done of any sludge proposed to be used for land application.

— Identifying and assessing possible alternative uses for the sludge, i.e., agricultural use, reclamation uses, use on forest land, parkland or other public lands.

— Determining landowner interest in land application.

— Providing information on soils, erosion and water resources which would permit initial screening of potentially suitable land for sludge application.

— Working with municipal wastewater treatment officials to determine possible constraints on land application.

— Identifying appropriate crops or other vegetation for sludge application.

b) In designing a land application project:

— Coordinating efforts by resource specialists to determine the acceptability of individual sites for land application.

— Providing information and analysis about the timing of sludge application and the rate of application that is consistent with the capabilities of the land, current cropping patterns, or other uses of the land.

— Identifying any special management procedures (including changes in normal cropping patterns, conservation practices, pH management, and pollution minimizing measures) which might be needed.

— Informing landowners of any necessary restrictions on normal farming practices which would occur if sludge application takes place.

c) In applying sludge to the land:

— Making sure that the project meets federal and state criteria for the specific sludge application technique that is used, and that the application rate is appropriate.

— Helping landowners develop conservation plan incorporating desirable measures to control erosion or runoff from sludge-augmented lands.

— Making sure that any agreement between a landowner and a municipality serves the interest of both parties. Landowners in particular should be assured that the sludge is suitable for agricultural use, and should understand any limitations (such as temporary restrictions on growing crops for direct human consumption) that may be associated with their acceptance of the sludge.

— Making sure that the sludge delivery system (i.e. tank truck equipment, injection, or surface spreading equipment) is appropriate, and that modifications (such as floatation tires) are used as needed in order to adequately protect the land during sludge application.

— Working with landowner to insure that they successfully carry out any special management practices that may be needed, and that sludge application is done in such a way as to minimize disruption of normal farming operations.

d) In monitoring and follow up

Even when sludge is applied only once to a parcel of land, monitoring and follow up procedures are an excellent idea. This permits identification of any problems (such as water pollution) that could arise, and, moreover, reporting procedures that are used further the state of knowledge about land application of sludge. Conservation districts can assist in this process by:

— Making sure that landowners participating in projects understand from the outset the need for and agree to post-application monitoring by technicians.

Good Sludges for Land Application

— Coordinating or conducting monitoring of groundwater, surface water, soil quality, and vegetation on project sites in order to determine if any problems with heavy metals or other contaminants exist, reporting results on the monitoring process in order to further the state-of-knowledge.

— Recommending any changes in management practices (either by the municipality or the landowner) that would resolve problems, or improve the land application project.

— Monitoring yields of crops or other vegetation on land application sites.

— Establishing, when possible, control or test plots in order to compare conditions on sludge-augmented land with other land that has not been subject to sludge application.

Unless very low application rates are used, all sludges applied to agricultural land should be "good" or "clean" sludges: that is, their application to cropland as a source of nitrogen or phosphorus should not present an appreciable risk of contaminating soil, water, or food chain crops, or otherwise damage crops and other vegetation.

Thus, in every community, careful assessment of the sludge itself is the key first step in determining whether land application should be used. Under current federal regulations, the responsibility for such assessment rests with the operators of individual wastewater treatment facilities. Any farmer or other landowner who is considering land application should be certain that proper testing of the sludge quality has been conducted, and the sludge is acceptable for agricultural use.

In most instances, the most suitable sludge for land application in agriculture will come from municipal treatment plants which primarily serve residential communities. Such sludges are less likely to have unacceptable high levels of contaminants, and may have higher levels of organic matter and nutrients, than sludge from municipal plants which also process industrial wastes and storm drain runoff.

Briefly described below are the beneficial and potentially detrimental c ıstituents of sludge.

Organic Matter and Nutrients

The amount of organic matter in sewage sludge varies, but can be quite high—up to 50 percent by dry weight. Because the organic matter serves as a soil conditioner, application to the land may improve the tilth and the texture of the soil. Generally, the higher the degree of sewage treatment or sludge processing employed, the less the organic matter will be contained in the sludge. One benefit of land application of "good" sludges is that high levels of treatment to reduce organic matter content are not generally required since these substances will be recycled, although special attention to assure adequate pathogen kill may be necessary. Hence, overall community treatment costs may be reduced.

Sewage sludge also contains variable amounts of nitrogen and phosphorus, as well as very small quanitities of potassium and many micronutrients. Because all of these materials are essential for plant growth, sludge can be used to supplement fertilizer regimes. Although concentrations of nutrients in sludge are relatively low, sludge application rates can be adjusted so that most of the nitrogen and phosphorus requirements of many crops can be met—provided that heavy metals or other contaminants do not restrict application rates. Potassium concentrations in sludge are generally too low to meet the needs of most crops, and supplemental fertilizer usually is required.

Research on crop yields and vegetation response to "good sludge" is being conducted. Most of the research results to date indicate that crop yields on sludge-amended land compare favorably with the use of commercial fertilizer. An added benefit for farmers is that most municipalities provide the sludge to farmers at little or no cost.

Heavy Metals and Toxic Materials

Concern about heavy metals and other potentially toxic materials in sewage sludge remains a constraint to greater use of sludge in agriculture. While scientific knowledge about these substances—and how to manage them has evolved rapidly, there are still areas of disagreement about what levels of contaminants are acceptable for sludges applied to agricultural land.

The presence of small concentrations of some heavy metals in the sludge—"trace elements" such as zinc, copper, and selenium—need not be considered a liability. In fact, very small concentrations of such trace elements are essential for plant and animal metabolism, and are often present in deficient amounts in the soil. Thus, when sludge contains proper concentrations of these elements, it may help to make up nutrient deficiencies in soils and crops.

At higher concentrations, however, such trace elements are potentially toxic. Two contaminants frequently found in sludge—a heavy metal, cadmium, and a group of persistent organic compounds, polychlorinated biphenyls (PCBs)—have no known beneficial metabolic effects, and can be extremely toxic. Thus, concern about possible soil, water, or crop contamination, and potential impacts of such toxic substances to animals or man has arisen.

As has been mentioned, heavy metals or other contaminants may be a problem in communities where industries discharge wastes into municipal systems, or where combined stormwater and wastewater treatment systems are employed. Sludges from such treatment facilities may not be appropriate for land application unless pretreatment of industrial wastes or other measures are employed to reduce contaminants to acceptable levels. While such measures may make previously unsuitable sludges acceptable for land application, careful monitoring and periodic

testing of the sludge is needed to assure that the improved quality is maintained. Landowners should not accept such sludges unless they have assurance that proper quality controls are in place.

The federal government and some state governments have established criteria for determining the suitability of sludge and sludge application rates for land application. At the federal level (see box below), interim criteria have been established for cadmium, and polychlorinated biphenyls (PCBs)—two substances thought to be of major concern. Additional guidance also exists for determining threshold levels for other contaminants in sludge. Unless their use is very carefully managed, sludges with relatively high concentrations of such heavy metals as zinc, nickel, lead, mercury and chromium should not be used for land application, even though formal regulatory criteria have not yet been issued by federal agencies. In some instances, the state criteria are more restrictive than the federal criteria and guidance.

Pathogenic Bacteria, Viruses and Parasites

Since raw sewage contains pathogenic bacteria, viruses and certain parasites, any sludge disposal method can involve potential risks of transmitting diseases to humans. Most of these organisms are destroyed during sludge processing at a sewage treatment plant, but some pathogens survive most treatment processes. In the case of land application, transmission of disease could theoretically occur through direct exposure of farm and sanitation workers to the pathogens, contamination of surface water, groundwater, or crops, or by vectors (carriers of disease organisms, such as rodents or insects).

To minimize the potential for public exposure to pathogens, EPA has established special criteria to be used in processing the sludge prior to land application, timing the application of sludge, and managing the land after sludge application. All sludge applied to cropland must undergo a process which significantly reduces pathogen levels (such as aerobic and anaerobic digestion, air-drying, heat-drying, irradiation, composting and lime stabilization). Public access to land application areas is to be limited for one year after land spreading, and grazing by animals that produce products consumed by humans is prohibited for at least one month.

Processes which reduce pathogens to very low levels must be utilized in those instances where crops are grown for direct human consumption within 18 months of land spreading. This further requirement does not apply if the sludge does not actually come into direct contact with the edible portion of the plant.

Care should be taken to assure that farm workers and operators who are directly exposed to sewage sludge receive proper immunizations against disease, and are aware of the need to follow proper sanitation when exposed to areas where sludge has been recently applied.

Resistant parasites in the sludge are also a potential concern. For example, the ova of **Ascaris lumbricodes**, a parasitic intestinal worm in humans, can be excreted by affected humans into sewage. Since the ova are relatively resistant to most wastewater treatment and sludge stabilization processes, they may be present in the sludge when it is applied to the land.

While there is always a potential for transmission of disease from sludge to humans, the experience to date with land application has been a good one. Studies made at actual land application projects investigating potential public health concerns to date have recorded no instances of disease transmission attributable to land application of sludge where proper management practices were followed.

Federal Criteria on Heavy Metals and Toxic Materials

Sludge was defined by Congress as a solid waste in the provisions of the Resource Conservation and Recovery Act of 1976 (acronymed RCRA), which regulates the disposal of hazardous and nonhazardous solid wastes. EPA regulations under RCRA do not list sewage sludge as hazardous waste unless tests show on a case-by-case basis that an individual sludge is hazardous. Initial responsibility for such determination rests with the owner or operator of a publicly owned treatment plant. Any farmer or other land operator receiving sludge for land application should be sure that an assessment of the sludge has been conducted and that testing shows that the sludge falls within acceptable quality parameters for land application.

An ongoing federal interagency effort (involving the Environmental Protection Agency, the Department of Agriculture, and the Food and Drug Administration) is underway to establish criteria or tolerance levels for sludge-borne contaminants in food chain crops.

At the present time, "threshold" criteria and associated management practices for land application of sludge have been established for cadmium and polychlorinated biphenyls (PCBs). These criteria are enforceable, though interim in nature, and subject to change.

PCBs (as well as certain other persistent organic compounds) tend to concentrate in fatty tissues of animals, and could be biomagnified in the food chain. Research conducted on plant uptake of PCBs or related compounds suggest minimal uptake by forage and grain plants. However, direct indigestion of PCBs by grazing animals is a potential problem where surface application of sludge containing these compounds has been used.

The present federal criteria for land application of sludge containing cadmium and PCBs are increasingly more restrictive as the probability of human food chain involvement increases. The least restrictive category is for land application in which no human food chain involvement is likely, followed by the use in feed grain and forage crop production. The most restrictive category includes sludge use in the production of crops grown for direct human consumption.

Additional guidance exists about acceptable levels of other heavy metals (e.g., zinc, copper, and nickel) in land application of sludge. High levels of these materials in a sludge may preclude its use in land application. Several states have established their own regulatory criteria for contaminants in sludge which may be more stringent than federal requirements and guidance.

Although there remain scientific disagreements about acceptable levels of potentially toxic materials in sludge, the use of "clean" sludge in land application is the best way to minimize potential hazards. According to a joint policy statement on the use of sewage sludge in the production of fruits and vegetables issued by EPA, USDA and FDA in 1981, "the use of high quality sludges, coupled with proper management precautions, should safeguard the consumer from contaminated crops and minimize any potential adverse effect on the environment."

Factors to be Considered in Land Application

Although land application is simple in concept, the actual design of a good program is quite complex. Communities seeking to implement a land application approach need to draw upon the expertise of many different specialist in the technical design of a program, and in implementing and monitoring a sludge application program.

Experience with land application of sludge is growing rapidly, and there now exists a fairly well defined government and private support structure which can assist communities in the design of an appropriate land application program. In many instances, the community will be able to draw upon the technical expertise of local conservation districts, forest and agriculture extension agents, university professors, and consultants to design program options, and work with individual landowners participating in the program. Federal agencies, including the U.S. Environmental Protection Agency, several agencies within the U.S. Department of Agriculture, and the Food and Drug Administration, also provide technical information and other assistance or guidance.

On the following pages, many of the issues associated with land application are discussed. The discussion is intended to be general in nature, and should not be construed as providing specific guidance to a community that is assessing land application alternatives.

Addressing Public Concerns

Even the best designed land application program can falter if it does not gain public acceptance. Although land application projects generally are not resisted as strongly by nearby residents as are sanitary landfills, public acceptance problems can arise—especially when land application sites are located near residential development or when little effort is made by public officials to deal with the legitimate concerns of nearby residents about odors, health effects, and property values, as well as the more generalized public concern about possible contamination of food chain crops.

These concerns are not frivolous. Improper land disposal of sludge can indeed produce odors, or contaminate the surface water, groundwater, soil or vegetation with pathogens, heavy metals or other toxic materials. Were such problems to arise, property values could be affected as well. Moreover, in some situations it has been proposed that notations be made on the deeds of private land used for land application. This is intended to permit long term monitoring of the land effects of land application, and to guard against changes to incompatible future land uses. While there are advantages to such proposals—in terms of monitoring longterm effects and potential problems associated with land application—landowners will be wary of accepting sludge under such conditions.

Another problem is psychological. Although land recycling of human wastes has been used in Europe, Asia, and other areas of the world for centuries, the use of such practices has been much more limited in the United States. Most Americans have always had a preference for engineering approaches to sewage disposal. From an environmental and economic perspective, the engineering approaches in many instances may be less cost-effective than land application techniques, but psychological opposition on the part of the public tends to be high.

Thus, dealing with public concerns is an essential component of many land application programs. Fortunately, land application usually does not present as many risks as some other methods of sludge disposal. An improperly selected and operated landfill site, for example, presents a far greater risk of groundwater contamination or production of odors because much larger volumes of wastes are disposed of on a site.

In land application, the sludge is spread infrequently and in relatively small volumes on many sites; thus the potential for localized problems is reduced. Moreover, because land application can improve the physical properties of the soil and boost crop yields, the value of the land for agricultural use may actually rise. Thus, farmers and other landowners who are participating in a land application program are likely to take up the case of land application with other farmers in a far more persuasive manner than government officials. (By contrast, no one wants to live next to a landfill site—no matter how necessary such facilities may be.)

Because resistance to sludge land application projects is greatest from nearby landowners and residents, selection of sites that are relatively isolated from residential or commercial development and other nonfarm activities can help reduce public opposition. One comparison of 16 land application sites and their abutting land uses found that there was no public opposition to the five projects in which low intensity land uses (defined as forests, abandoned strip mines and sand dunes) were adjacent to the site. Medium intensity abutting land uses—active strip mining, and grazing or ranching—brought more intense public opposition. (Only one of the eight projects in this category encountered no opposition; the others encountered lawsuits or individual opposition by abutting landowners.) In the case of high intensity abutting land uses—residential development and intensive agriculture —all three of the proposed projects become the subject of legal actions which eventually prevented these projects from being implemented.

Assessment of the Sludge

As has been mentioned, the first step in any land application system must be analysis of the sludge itself in order to determine its suitability for various land application techniques. Because analysis of the sludge is the responsibility of the operator of the municipal treatment plant, landowners or other communities considering acceptance of sludge should insist that sufficient testing has been conducted to assure that the sludge is suitable for the intended beneficial use. (Agricultural uses of sludge, for example, generally involve more restrictions on heavy metals than when the sludge is used in surface mine reclamation.) The U.S. Environmental Protection Agency recommends that a minimum of 3 to 6 samples of sludge should be analyzed over a one year period to determine its suitability for land application. More frequent sampling may be needed in many situations.

Key components of sludge analysis should include, among other things, analysis of heavy metal concentrations (especially cadmium, copper, nickel, lead and zinc); specific persistent organic compounds (such as PCBs); and pathogens, in order to determine limitations on land application. Other important information which should be determined include:

— Current and future levels of sludge production, in order to determine the likely range of land requirements and estimated costs.

— Nitrogen, phosphorus and potassium content, to determine value of the sludge as fertilizer, and proper application rates for farm use.

— Testing for volatile solids to determine likely odor problems.

Various measures can be taken to reduce levels of heavy metal concentration in

sludge prior to land application. These include pretreatment by metal using industrial sources discharging into municipal systems, and changes in the wastewater and sludge treatment processes utilized by the sewage treatment plant.

As has been mentioned, EPA, USDA, and FDA are surveying available information in order to help establish final land application criteria and tolerance levels for heavy metals, pathogens and other sludge contaminants for various beneficial uses.

Land Availability

On a national basis, the physical availability of land for sludge application is not a problem. In fact, according to one estimate, only two percent of all cropland in the United States would be needed for land application of **all** sewage sludge likely to be produced by 1985. Forest land, surface-mined land, range and pasture, are also potential sites for sludge application.

At the local level, however, a variety of constraints affect land availability. In some heavily urbanized states with relatively little cropland per capita, widespread adoption of land application by communities could require a fairly high proportion of existing cropland. In Florida, for example, it is estimated that about 20 percent of the state's cropland would be required if all sludge produced in the state by 1985 were applied to cropland. Similarly, in New Jersey, 55 percent of the cropland would be required. While land application of all sludge is not likely, some localities that have high levels of urbanization (either concentrated or dispersed) may experience difficulties in locating suitable cropland for land application in the future.

As a result, some land application projects involve transport of the sludge to a neighboring or more distant jurisdiction. Transportation costs are a key factor here, since transporting sludge long distances usually involves very high costs. Moreover, sludge is applied infrequently when it is used on farmland; in many cases, it is applied only once in several years on a specific field because of regulatory limitations, or possible interference with cropping practices. Therefore, in some instances, cities have used publicly owned land where frequent repetition of sludge application is possible. In such cases, production of agricultural crops is not the primary purpose of the program.

While transportation distance is centrally important, shipment of sludge well over one hundred miles for land application has proven feasible for some large cities. Philadelphia and Chicago transport large volumes of sludge to distant sites for use in surface mine reclamation; in both instances, land application has been cost-effective. A key factor in these two cases is that the sludge is shipped in large volumes to a centralized area which will have sites available for land application of sludge over a number of years. In these cases transportation arrangements such as longterm barging contracts, use of pipelines, and special back haul arrangements in which sludge is hauled to reclamation sites in the same trucks which haul coal to the city were developed.

Site Characteristics

For many smaller communities, finding farmers or other landowners willing to apply sludge to their land has not been a major problem. In fact, in some instances, municipal land application programs have been established because of interest expressed by local farmers. However, other communities may have greater difficulties in locating private landowners who are willing to accept sludge. In such instances, utilization of publicly owned land (such as highway median strips, parkland, or specially dedicated land) may be an alternative worthy of consideration.

Whether private or public land is to be used, however, it is essential that the site be carefully assessed to determine whether land application is appropriate, and, whether special soil conservation or other management practices will be needed. Most communities that are considering landspreading can tap the professional expertise of local conservation districts, and extension agents in order to assess site conditions on specific farms or other private lands. Prior to any sludge application, all potential sites should be visited by resource specialists in order to determine limitations of the land, or the need for compensating management practices.

In communities where limited land is available, initial screening of land within an economically affordable distance of the treatment plant (usually within a 30 mile radius or less) is an advisable first step in determining whether land application is feasible. Often, considerable information about land use patterns, soil conditions, site geology and hydrology, and climatic limitations already will be available. In general, land near residential, commercial or other intensive development should be excluded because of possible health concerns, odor problems and likely political opposition. When feasible, land within the same local jurisdiction which produces the sludge should be considered first. Even though some communities transport their sludge to neighboring or more distant jurisdictions, such jurisdictions often resist receiving another community's sludge. While agricultural land application is the most common means of land application, other potential uses (such as use on forestland, surface mined land, highway median strips, and so forth) should be kept in mind. To the extent possible, attitudes of residents about land application should also be taken into account in order to avoid political "hot spots." Very often, local conservation district personnel can provide information about the expected attitude of farmers on this subject.

Soils and Other Physiographic Conditions

Once a general understanding of the feasibility of land application in an area is gained, more specific analysis of topographic and geologic conditions, soil characteristics, and other physiographic factors is needed to determine whether a specific site is appropriate.

In order to minimize the potential for runoff and erosion, relatively flat land generally is preferred. Land that has a slope of more than 4 to 6 percent generally should not be used without special management or conservation practices which reduce runoff. Sites subject to flooding should also be avoided, since this will substantially increase the risk of water pollution. An understanding of subsurface geology is also essential in those instances where contamination of groundwater could occur with improper sludge application.

With proper management, soils with a wide range of physical, biological and chemical properties can be used for land application. While few soils are completely unsuited for sludge application, some are far better than others.

Since all sewage sludges contain at least small concentrations of heavy metals, the pH of the soil is an especially important management factor. The solubility of most heavy metals tends to increase as soils become increasingly acidic. This means that uptake of metals by plants and downward leaching of metals towards the groundwater will tend to be greater with

acidic soils. Therefore, a soil pH of 6.5 or above is generally required when sludge is applied to the land. Moreover, a pH of 6.5 may need to be maintained for several years after application, since heavy metals may continue to be present in the soil in an insoluble form. Lime is usually applied to raise the pH of acidic soils. Annual monitoring (with lime additions where necessary) should be continued after sludge applications.

When sludge is used in commercial farming, both the constraints on sludge and the possible need for liming should be understood by the landowner prior to any sludge application. Considerable evidence now exists that proper use of high quality sludge can safely improve crop yields. Moreover, lime additions are often beneficial to crop growth on many soils, and are frequently used anyway by farmers. However, in some instances where proper sludge use practices are not followed, an excessive buildup of plant available heavy metals in the soil could occur and result in reductions of crop yields. While yields may rebound subsequently, farmers need assurance that the sludge they receive is of good agricultural quality and that appropriate sludge application rates and liming procedures are followed to adequately manage any metal additions to the soil in a manner that will not reduce expected crop yields or quality. Where sludge application is not compatible with commercial farming, other alternatives (such as land application on noncommercial grassland owned by the municipality or on publicly or privately owned forest land) may still be possible.

Determining Application Rates

Where metals or other contaminants are not a potential problem, the determination of how much sludge to apply to crops is based on the nutrients needed to achieve the intended yield, just as is the case with commercial fertilizer. Crop uptake of nitrogen (which is the most concentrated nutrient) generally is the primary consideration. Usually, phosphorus needs will also be met. Even when nitrogen is applied at rates equivalent to those recommended for commercial fertilizer, however, supplemental potassium fertilizer additions may be needed for some crops.

Sludge application rates may be limited by the presence of heavy metals in the sludge, soil response to such metals, and uptake of such metals by the individual crop grown. As has been discussed, cadmium is the heavy metal which is most likely to reduce application rates below levels needed to supply crop nitrogen needs. Depending upon the individual characteristics of the sludge, however, other metals, such as zinc, copper, lead and nickel may affect application rates in some instances.

Because of the number of variables involved, technical expertise is needed in order to determine appropriate application rates (both in quantity and in frequency) for individual sites. This usually requires a coordinated effort on the part of agronomic professionals and water quality specialists. Researchers have developed a number of different equations which can be used to determine proper sludge application rates.

Selecting the Crops

From the perspective of the farmer, land application should be conducted in such a way as to require minimal disruption of normal farm operations and cropping patterns. Thus, timing of sludge applications in order to meet cropping needs is essential.

For example, where row crops such as corn are grown, sludge application is not possible except before plowing or after harvesting in most instances. (A possible exception is where ridge and furrow application is utilized.) Similarly, requirements and restrictions on the timing of sludge applications when crops are grown for either direct human consumption or as feed for animals whose products are consumed by humans must be taken into account. In some areas, fruit and vegetable processors may be reluctant to purchase products from growers that have applied sludge on their land, even when proven precautions have been taken. Thus, growers should be cognizant of the attitudes of their clients prior to land application.

Different crops vary in their uptake of heavy metals and other contaminants. Moreover, there is a variation noted within individual plant tissues: seed, fruits and vegetables, for example, may absorb heavy metals at rates different than stems and leaves.

Conservation Plans

Although seldom required by state or local regulations, farmers seeking to have sludge applied to their land may wish to develop a soil and water conservation plan in order to assure that farm management and sludge application objectives are mutually reenforcing. The plans can help to identify possible problems—erosion, water contamination, and so forth—that could arise from improper land application, and any post application measures that are needed to accommodate sludge application. They can also identify appropriate farm management practices, timing of sludge applications, and other factors that may limit sludge use.

Liquid, Dewatered or Composted Sludge?

Some large communities partially dewater sludge in order to make it easier to store or transport, and to minimize odor problems. For the smaller communities, however, delivery of liquid sludge is usually a less costly alternative. Farmers often prefer liquid sludge because it easier to apply evenly on fields, and because the sludge delivery truck's driver will usually spread the sludge on the field.

Because of the energy costs involved, it can be costly for the community to dewater sludge. But transporting liquid sludge long distances can be much more expensive than transporting dewatered sludge due to the difference in water content. Unlike liquid sludge, the dewatered sludge can easily be deposited at an on-farm storage area allowing the farmers to apply the sludge at their own convenience. However, at times when immediate application is not appropriate (such as in the winter or during the growing season), storing of the sludge can be a problem.

High quality composted sludge can be an important option for many communities. Composted sludge is easy to store and package, and presents minimal potential for odor problems. Often, local farmers and gardeners will transport compost provided by the municipality. Some municipalities market sludge composts, and thus partially defray treatment costs.

Techniques for Applying Sludge

Sludge can be applied to either the surface or the subsurface of the ground. Some states require that all sludge be incorporated into the ground during or immediately after application. This is designed to control odor problems, reduce potential pathogen problems, and minimize the potential for sludge runoff to surface waters. Different incorporation methods include plowing to create a furrow in which the sludge is

deposited and covered, discing, and direct subsurface injection. In some instances, the municipality provides the equipment needed to apply and incorporate the sludge; in other instances, the farmer is responsible for sludge incorporation into the soil.

Even where not required by regulation, soil incorporation of sludge is not uncommon. Since less organic matter and nutrients are lost through volatilization or runoff, it can have beneficial effects for the soil and plant growth. However, incorporation generally cannot be done during the growing season, and is more difficult to accomplish during wet weather or when the ground is frozen.

a) Tank Truck Application

Although pipelines, barges, trains and other conveyances are often used to transport sludge from large cities to disposal sites, smaller communities using land application will most likely truck the sludge to nearby farms. In most instances where liquid sludge is involved, the tank truck will apply the sludge on the land by driving across the field. Where incorporation into the ground is desirable, equipment following immediately behind the truck or attached to it can be used.

The principal advantages of a tank truck system are low capital investment for the community and ease of operation. The system is also flexible in that a variety of application sites can be served, such as pastures, cropland and even tree plantations. Disadvantages of tank truck spreading include inability of trucks to cross fields in wet weather, possible compaction of the soil due to repeated truck trips across fields, and a limited ability to apply sludge during the growing season. Flotation tires can help reduce problems associated with wetness.

Improper application of liquid sludge by inexperience drivers or through use of inappropriate distribution devices can be a problem. The simplest form of tank truck distributes liquid sludge from a conduit at the back or side of the vehicle. Uneven application on the field can result, since distribution depends on the speed of the truck and the slope of the ground. Because such tank trucks need to make repeated trips across the field, compaction problems are more pronounced with this equipment.

Splash plates and perforated T pipes can provide more even distribution, but these systems still operate on gravity flow. Higher rates of application will occur at the beginning of a trip across the field, or when the truck is moving up a grade, unless proper compensating adjustments are made to the speed at which the truck is driven. One modification of the basic process is to mount a spray apparatus on a truck so that a wider, more even area can be covered by each pass.

b) Irrigation

Spray irrigation equipment that is capable of handling solid material without clogging is sometimes used for sludge application to agricultural and forested lands where immediate incorporation is not required. Because of concerns about pathogens and odors, it is not recommended for use on fields that produce crops consumed raw by humans, or in areas where wind is likely to carry aerosols to nearby residences. Care must be taken to avoid excessive applications of liquid sludge since sludge covered foliage will receive less sunlight and may result in damage to sensitive plants. In some circumstances, spray irrigation is advantageous, however. It can be used throughout the growing season, as well as on land that is too wet or too rough for tank

Federal Laws Relevant to Sludge Disposal

Several federal laws and agencies are actively involved in assisting states and localities in the management of sewage sludge. In addition, many states have established their own criteria and standards for sludge disposal which, in some instances, may be more stringent than federal requirements. The major federal laws include:

The Clean Water Act of 1977: This act amended the 1972 Federal Pollution Control Act Amendments, by tying sludge disposal to the National Pollutant Discharge Elimination System (which requires permits for regulated point sources discharging into navigable water bodies), by authorizing minimum federal standards for sludge disposal and utilization, by authorizing the development of pretreatment standards for industries which discharge their wastes into municipal wastewater treatment systems, and by encouraging beneficial use of sludges that conform to federal standards. Increased levels of federal construction grant funding were authorized for innovative and alternative wastewater treatment and sludge management technologies that include beneficial use of such sludges.

Resource Conservation and Recovery Act of 1976 (RCRA): RCRA gives the EPA broad statutory authority to regulate the disposal of an array of hazardous and nonhazardous waste materials. Sludge, within the definition of the act, is defined as solid waste. Also, the Act authorizes the EPA to identify sludge as a potentially hazardous waste material when an individual sludge contains unacceptably high levels of metals or other contaminants. Responsibility for informing EPA of the characteristics of an individual sludge which makes it potentially hazardous rests with the individual operator of the treatment plant.

The Act also authorizes financial assistance to states and localities for preparation of solid waste management plans and technical assistance on development of appropriate solid waste disposal processes. Research and development provisions are intended to encourage better technologies for disposal of solid wastes and for resource conservation.

Other Relevant Federal Statutes

The Marine Protection Research and Sanctuaries Act of 1977: Provides for phasing out of ocean dumping of sludges which may irreparably degrade the marine environment. The Act also gives EPA authority to establish compliance schedules for land based alternatives to ocean dumping.

The Clean Air Act: Provides the basic structure for regulating of air pollutants, including air pollutants emanating from sewage sludge incineration.

Safe Drinking Water Act: Specifies a coordinated approach with RCRA to prevent contamination of drinking water.

Toxic Substances Control Act of 1976: Provides for a coordinated approach for disposal of toxic wastes.

trucks. One of its most promising uses is on forest land (provided spraying is not conducted near public recreation areas).

Application of sludge by ridge and furrow irrigation is similar to normal ridge and furrow irrigation practices used in agriculture. However, because of the solids in the sludge, the slope of the furrow is of greater importance. When the slope is not appropriate, solids may collect at the beginning of the furrow, and cause ponding.

Monitoring

Unless only very limited applications of sludge are involved, careful monitoring and follow up procedures are usually required in land application of sludge. The sludge itself should be re-assessed periodically in order to determine whether changes have occurred in its composition which could affect land application rates. Analysis of the soil and vegetation to determine levels of heavy metals and persistent organic compounds should also be conducted, along with monitoring of soil pH, and surface and groundwater conditions. As has been mentioned, maintenance of a pH of 6.5 or higher through lime application or other techniques generally is required on cropland in order to minimize the potential for plant uptake or leaching of excess heavy metals. Such a pH is within the optimal range for production of most crops, although there are exceptions.

Landowners that are participating in a sludge application project should be informed at the outset that monitoring of conditions on their land may be needed. Very often, monitoring activities are undertaken by conservation district and extension service personnel who are familiar with and sensitive to the concerns of landowners. In general, the monitoring requirements for use of high quality sludge at appropriate application rates should not be much more involved than normal agricultural soil test ing.

Case Studies

The following case studies briefly discuss several examples of involvement by agricultural agencies in land application. The specifics vary in each instance, but all involve a concerted effort to assure that land application is done in a way that safeguards the best interests of landowners and the land itself.

Monroe County, New York

Since 1975, Monroe County—the home of the city of Rochester—has been applying part of its municipal sludge to farmland. The program has the active support of area farmers, who are assisted in all stages of the land application program by the Monroe County Soil and Water Conservation District. Other agricultural agencies—including the Extension Service, and Cornell University agronomy specialists—also are actively participating in the program.

As often happens in land application programs, the genesis of Monroe County's project was public dissatisfaction with a traditional means of sludge disposal. In 1974, the county manager (who was formerly a director of the conservation district) received complaints about odors arising from an incinerator used to dispose of sludge from one of the county's treatment plants. The plant, located near Lake Ontario, collected waste from nearby residential subdivisions but no industrial facilities, and was therefore found to be a "clean" sludge.

Following initial meetings between the county manager, Monroe County Conservation District Officials, and the Pure Water Board (the municipal sewage treatment authority), the county decided to test a land application program on a 175 acre parcel of publicly owned land. The district, along with several other local agenices, conducted extensive tests at the site. Monitoring wells, retention ponds and other facilities were established. Actual sludge application began on the publicly owned site in the fall of 1975.

In 1977, the County expanded its program in order to make sludge available to nearby farmers. Prior to initiating the program, the Monroe conservation district identified farmers interested in the programs, evaluted site conditions on local farms, and worked with farmers to upgrade conservation plans to take into account possible changes needed to accommodate sludge application. The district is continuing to work with interested farmers, and oversee the process of securing requisite governmental approvals.

Farmers who participate in the program receive the sludge free of charge. In return, they sign an agreement with the county under which they are not permitted to grow root crops on their land for three years. In addition, they agree to provide access to the land to government officials responsible for monitoring crops, soil and water conditions after land application.

Currently, about 12 farmers have received the sludge on a one time application basis from one of the County's three main sewage treatment plants. The sludge is lime stabilized prior to application, in order to reduce pathogen levels, and is dewatered to a 20% solids content. But it is not otherwise treated, and therefore contains valuable organic matter and nutrients. Available nitrogen content is about 4 percent, which is typical of many sewage sludges. Because the sludge comes from residential neighborhoods, it has low concentrations of heavy metals, and other contaminants that might otherwise be a problem. These low levels of contaminants have been verified by more than 45 separate analyses of the sludge.

Truck drivers employed by the Pure Water Board haul the sludge to the application sites. It is immediately incorporated into the soil with a moldboard plow, disc, and cultipacker provided by the county. The operator then checks the land to make sure that full incorporation has been accomplished and completes any additional coverage by hand if necessary. Thus, the application process requires minimal labor on the part of the farmer.

Staff of the Monroe conservation district estimate that the entire cost of the land application program—including transportation and personnel expenses associated with applying and incorporating the sludge—are about 80% of the previous operating costs of incinerating the sludge.

Protection of the land is built into the program, through state and local requirements, and monitoring. Permits from the New York State Department of Environmental Conservation are required prior to land application at each site. In addition, special conditions—such as prohibiting land application within 200 feet of a streambank, or near grassed waterways—are required. The Monroe Conservation District assists with monitoring of groundwater, runoff, and heavy metals (which are analyzed by the county), and has established some test sites on nearby farmland in order to compare conditions. Soil samples are tested at

Cornell University. In the early days of the project, district officials found that a need arose for relatively intensive observation of application procedures by the county. As county drivers have become more experienced with sludge application, however, the need for supervision has been less pronounced.

Currently, none of the privately owned farmland enrolled in the program has been treated with more than one application of sludge. Because of the low heavy metal content, the one time sludge application rate is rather high—averaging 20 dry tons per acre. The program is very popular with nearby farmers; as a result, far more private land had been evaluated and approved for sludge volume. District personnel have found that the sludge has helped to quickly reestablish orchards on land in which old trees have been cleared, and has had beneficial effects on corn and wheat yields.

Another sludge application activity being investigated by the district involves planting of hybrid poplars as a biomass energy source. This experimental project began in 1979, with the establishment of a district energy committee. The committee is investigating the effects of different levels of sludge application on poplar growth. Eventually, the poplars will be harvested and processed for ethanol and butanol production. (Some research on hybrid poplars suggests that they can be planted and harvested on two year rotations to produce 1,500 gallons of ethanol and butanol per acre per year.) Lignin byproducts of this process can be reformulated into pressed lumber, and other products can be pelletized into livestock feed. If the experimental project succeeds, it is possible that sludge from other Monroe County sewage plants will be utilized.

Ohio Farm Bureau Program

Since 1978, the Ohio Farm Bureau has been coordinating an experimental field investigation program of land application in five Ohio counties. The project involves comparison of land application under controlled conditions in which some farmers receive municipal sludge, while others do not. The project, funded through an EPA research and development grant, involves extensive cooperation with Ohio State University researchers who are conducting much of the technical analyses and assessment.

The requirements of the program specify that participating counties provide sludge of acceptable quality for agricultural use, as defined by State criteria. This led to the deletion of one county from the program, when it was discovered that the municipal sludge from one city contained relatively high levels of heavy metals.

In all, some 100 farms have been involved in the project, with about half of the farms receiving the sludge, which is delivered in a thick slurry, and the other half with similar soil conditions receiving no sludge. An extensive monitoring program, undertaken by Ohio State specialists and extension personnel, is utilized in order to test soil and water conditions, livestock health, and human health on both the sludge-augmented farms and the control farms. To date, there is no evidence of significant differences between the two.

The program also involves yield-comparisons conducted on sludge augmented land, land treated with commercial fertilizer at prescribed rates, and control plots (provided by the agricultural extension service at Ohio State) where neither sludge nor fertilizer is applied. Preliminary results show sludge-augmented land outperformed the control plots in all cases, and performed nearly as well as commercially fertilized land. The key difference, of course, is the cost. Participating farmers do not pay for the sludge—and, in fact, are given a small fee ($150) at the end of the project. Ohio Farm Bureau personnel estimate that even if municipalities charged farmers half the cost of an equivalent amount of commercial fertilizer, farmers would come out ahead. It has been reported that some farmers who are part of the control group are eagerly awaiting the end of the project so that land application may begin on their land.

The success of the Ohio Farm Bureau Program has spurred interest in land application throughout the rest of the state. For example, in the Toledo area, farmers have been willing to pay a private contractor for sludge applications as a phospherous fertilizer source. The Ohio Farm Bureau has also worked with other states (including Arkansas and New York) to help institute well managed land application programs.

Lewis County, Washington

Although not often required by regulatory agencies, a good conservation plan can identify and address potential problems in land application of sludge. Although most farmers are aware that conservation districts provide assistance in preparing such plans, many private companies and some local governments that are involved in sludge application projects may not be.

Two Lewis County, Washington projects involve conservation plans to demonstrate the advantages of utilizing the capabilities of soil and water conservation districts in the design of a land application program. One of the projects being conducted involves reclamation of surfacemined land owned by the Washington Irrigation and Development Company (WIDCO), a subsidiary of a Spokane power company. The other is a county owned and operated sludge management facility. The Lewis District was a very active participant in site selection and in preparation of conservation plans for both of these projects, which are now operational.

The WIDCO project began in 1977, with an informal research effort designed to test the suitability of using sludge from Seattle (located about 50 miles from Lewis County) in reclaiming surface-mined land. Early in the project, WIDCO contacted the Lewis Conservation District, in order to identify appropriate sites for conducting the land application program, and for assistance in preparing a conservation plan. The district assembled a team of specialists—a forester, soil scientist, wildlife biologist, and engineer—to determine basic site conditions, and to recommend appropriate conservation actions. Factors such as what plant materials to use, and sediment and runoff problems were addressed by the conservation plan. Vegetation field trials were begun on some sites; research to date suggests that the sludge outperforms commercial fertilizer in stimulating plant growth.

Now that the project is operational, District involvement is less intense. WIDCO anticipates that, by the end of 1982, all of the sludge from Olympia, Centralia and Chehalis, as well as 35 percent of the sludge from Seattle may be used in its reclamation project.

District involvement in the County owned and operated project consisted of recommending an appropriate site for the facility which is used to manage sludge, and in preparing a conservation plan which the County follows in management of the facility.

Somerset County, Pennsylvania

Located 200 miles from Philadelphia, Somerset County is helping one of the country's major cities—Philadelphia—dispose of its sludge. In the process Somerset County is helping to solve one of its own

problems—reclaiming surface mined land. Since the beginning of the project in 1978, the Somerset County Conservation District, together with other agricultural and natural resource officials, have been actively involved in helping to oversee and carry out the project.

Philadelphia's sludge disposal problem began in 1975, when it was told that it would need to phase out ocean dumping of sewage sludge. The City then began a major effort to assess alternative means of sludge disposal. A central alternative was thought to be application of sludge for use in reclamation of surface mined land. Initial screening by the City identified several counties with areas of unreclaimed surface mined land that were thought to be promising candidates to receive the sludge, but political problems arose in most of them once serious discussions began about initiating actual projects.

Philadelphia's plan received its best reception (albeit not a warm one) in Somerset County—a county with many sites scarred by surface mining. After a somewhat hesitant approval by the county commissioners in 1978, the initial project began on a ten acre demonstration site. This generated immediate opposition on the part of many people in the county; when subsequent plans were announced to expand the sludge application program, even greater opposition arose. In order to help it determine whether continued sludge application was appropriate, the county commissioners, working through the Somerset Conservation District, formed a Stripmine Reclamation Advisory Board, consisting of district officials, Soil Conservation and extension service personnel, representatives of the state fish and game commissions, and a private landowner.

The Board was charged with responsibility for overseeing the monitoring of soils, water, vegetation and other conditions pertinent to the land application project in order to provide the county commissioner—and local citizens—with impartial advice about future projects. Through the use of RCA funds provided by the Pennsylvania Bureau of Soil and Water Conservation, an extensive, two year monitoring program was begun. Assistance in monitoring and evaluation has also been provided by researchers from the Pennsylvania State University, the Cooperative Extension Service, and the State Fish Commission.

Initially, sludge was applied at the land reclamation rate on a one time basis to four surface mined sites. Prior to application, these sites were either not reclaimed, or inadequately reclaimed. Indications to date are that the sludge has greatly improved soil conditions and plant growth. The reclamation process involves grading, liming, sludge addition and incorporation, then seeding of the plots with grasses and legumes. Extensive monitoring of the vegetation, soil, and groundwater has been undertaken to determine what positive or negative impacts of the sludge addition occur and whether future agricultural use of the land is desirable.

Actual transportation and application of the sludge is managed by a private company. To keep transportation costs down, the company transports treated and composted sludge from Philadelphia in the same large trucks that are used to haul coal from Somerset County to Philadelphia.

In 1981, the Somerset County Conservation District prepared a report which provides an extensive analysis of the first two years of monitoring data gathered from the project. In general, the report concluded that heavy metal loadings and contaminants were well within the conservative state guidelines that Pennsylvania prescribed for use of sludge in surface mine land reclamation. Most of the samples were within the even more stringent guidelines prescribed for sludge use in agriculture, as well, but tended towards the higher range

The Role of Entrepreneurs in Sludge Processing

Land application of sludge—almost by necessity—requires the active involvement of the private sector to succeed. Is there also a role for the private sector in processing and marketing sludge products? Joseph C. Horvath, a Hungarian born resource economist now living in Missoula, Montana, has staked his future that there is—and in the process is educating the public about the advantages of recyling composted sludge.

Horvath came to the United States following the Russian invasion of Hungary in 1956. After 20 years of working on a variety of environmental and economic problems, Horvath established Eko-Kompost, Inc., in 1977; the company now markets a sludge based compost—also called Eko-Kompost—to garden stores, greenhouses, nurseries and others in 12 states.

Situated on a 35 acre site adjacent to Missoula's municipal sewage treatment plant, the City's sludge forms the basis of Eko-Kompost. But the product also is augmented by a variety of other ingredients, which according to the company's promotional materials, make it a biologically rich rooting medium, soil conditioner, and organic fertilizer. First, the municipal sludge is mixed with animal blood, bone meal, sawdust, shredded bark and granite dust. Then it is composted for several weeks in a forced aeration system. Finally, it is screened and cured for an additional four weeks prior to packaging (it is also available in bulk) and marketing. According to company figures, heavy metal concentration in Eko-Kompost fall far below the levels for heavy metals recommended by EPA, USDA, and FDA.

Before marketing his product, Horvath had to seek and secure no less than 17 federal, state and local government permits. Eko-Kompost apparently cleared in flying colors; unlike some sludge derived products, its very low levels of heavy metals makes it safe for agricultural and home gardening use.

Eko-Kompost is catching on, and the company proudly provides a long list of testimonials to substantiate this point. But, as both a vehement proponent of a cause and as a businessman, Horvath would like to see a little more interest on the part of state officials and western mine operators in using his product in surface mine reclamation.

He has taken his case to everyone in the state government from the Governor on down, and has even taken the extraordinary step—for a businessman—of donating 120 tons of Eko-Kompost to a coal company for use in reclamation. "That particular acreage is so much better in vegetation that the others look sick in comparison," Horvath writes in the **Missoulian**, but adds, ruefully, "I could not sell one pound to them." Horvath admits that his personal crusade for recycling can be tiring, but he is not giving up. "I know my product, and now many thousands know that it works.!"

of acceptability. In order to protect unknowing people from purchasing a sludge treated property for possible incompatible land uses, the County is considering placing special notational information on the tax rolls which would permit individuals to obtain information about sludge loading rates, acres reclaimed and so forth. The monitoring program also found that water pollution resulting from runoff from stockpiled sludge could be a problem unless dikes are constructed around the stockpiles. The report provides a variety of recommendations to mine owners and operators on better practices for reclaiming mined land, and minimizing soil erosion and possible water pollution problems.

A centrally important recommendation—one that could help remedy concerns about future use of reclaimed land for agricultural use—deals with the wastewater and sludge treatment processes utilized by urban areas that are seeking rural land for sludge disposal sites. The report calls for more extensive pretreatment of industrial wastes, or for segregated treatment and disposal of industrial and residential wastes in order to avoid concerns about heavy metals and other contaminants.

Although opposition to the program still exists, the monitoring program, together with public meetings where the data has been discussed, have helped to relieve concerns about the project. To date, no substantial pollution or contamination problems have been identified, but the advisory board has identified and made public the potential problems associated with the project, and appropriate remedies and adjustments which would help alleviate these problems. As part of its continuing involvement in the land application program, the Somerset Conservation District is preparing an informational slide show which will portray the program and the results to date.

Racine, Wisconsin

Racine County, Wisconsin, located adjacent to Milwaukee, provides another example of how land application of sludge can help solve municipal treatment problems and at the same time further soil and water conservation objectives. Since 1977, when the county began its land application program, it has received sludge from the Milwaukee Metropolitan Area Sanitation Commission. More recently, two towns within the county—the City of Racine and Rochester—have initiated land application programs. The County land application program is administered by the Planning and Zoning Office, with the close cooperation of the Racine Soil and Water Conservation District. In Wisconsin, soil and water conservation districts are part of the county government.

The sludge is shipped to the county for land application in trucks owned by private corporations or by the municipal sewage treatment plant operator. These entities are responsible for providing analyses of the sludge to the Planning and Zone Office.

Under the Racine program, no sludge may be applied to the land unless a conservation plan for the farm is in effect. Transporters seeking to apply sludge to the land first query area farmers about their interest in receiving sludge. The transporter then submits a list of farms to the Planning and Zoning Office, which in turn provides the list to the Racine Conservation District.

The Conservation District then contacts the farm owner and prepares a conservation plan for the land. So far, roughly 50 such plans have been prepared. Prior to land application, appropriate conservation practices to prevent erosion, and reduce runoff or possible contamination of water sources are put into effect as needed.

Once a plan has been approved, the Planning and Zoning Office determines an appropriate sludge application rate for the farm. This takes into account heavy metals in the sludge in order to minimize possible buildup in the soil. A staff specialist has been hired to undertake this analysis.

The sludge is generally provided and applied for the farmers at no cost. In most instances, the transporter will apply and incorporate the sludge into the ground. (Incorporation is a county requirement and is encouraged by the state). In instances where farmers receive liquid sludge, the transport companies often apply the sludge to the land, and also incorporate it into the soil through discing and knifing equipment shipped to the site along with the sludge truck. Some semi-dried sludge is also applied to the land—sometimes by farmers with their own manure spreaders. This has caused some complications in the winter months, when the sludge must be stored since the state generally does not permit sludge applications on frozen ground.

Monitoring of the land application sites is conducted by the Wisconsin Department of Natural Resources.

Florence, Alabama

In many areas of the country, a "show me" attitude exists among public officials and the public at large about land application. In such cases, a demonstration project may be needed in order to identify the benefits and possible problems of land application.

That was the situation that confronted the water and sewer commission of Florence, Alabama, in 1973. Florence was confronted with what has now become a common problem for many communities: increasing volumes of sludge produced by its upgraded sewage treatment facilities.

The commissioners believed at the time that land application of liquid sludge might be a feasible solution to their problem. In 1973, the city was using 8 drying beds to

Crop Yields and Land Application: the Florence Results

The Florence—TVA project is still ongoing. Initial test results, presented at a 1981 meeting of the American Society of Agronomy, showed the following:

— A single application of sludge in 1978 resulted in higher soybean yields for three consecutive years than did annual conventional fertilization.

— In two of the three years, two levels of sludge application (11 and 78 metric tons per hectare) promoted higher yields of corn than did conventional fertilizer. (In the third year, conventional fertilizers outperformed the sludge, except in the case of the highest sludge application level of 78 metric tons).

— Production of seed cotton was initially lower on the sludge-amended land than on land treated with conventional fertilizer. However, in 1981, the cotton yields on both test plots were comparable.

Heavy metal concentrations were not found to be appreciably different in the vegetative tissues, grain or seeds of the crops grown on sludge-augmented land when compared with the crops grown with conventional fertilizer. There was a slight increase in zinc and cadmium concentrations in the sludge-amended lands, but the variation was found to be greater than would be attributable to the sludge itself.

dewater the sludge. If the use of drying beds was to be continued, an additional 12 beds—costing $200,000, and $10,000 a year in maintenance costs—would be needed. Moreover, drying the sludge didn't really solve the problem; it still had to be disposed of—by incineration, landfilling or through distribution to landowners. If land application of liquid sludge was feasible, processing costs could be reduced, and the problem of ultimate disposal overcome.

However, there were several impediments to implementing land application of liquid sludge. At the time, no guidelines existed at the state level for land application of sludge. Moreover, concerns existed about the environmental impact of land application, and possible effects on crops or other agricultural products. Florence has favorable soils for land application, but is underlined by limestone bedrock which dissolves easily. Thus movement of heavy metals and other contaminants in the sludge through the groundwater was thought to be a possibility. Therefore, prior to adopting a full scale land application program, a demonstration project seemed to be in order.

Fortunately, Florence's interest in land application was shared by the Tennessee Valley Authority (TVA), which provides waste management assistance to communities in the area, and has a major agriculture and chemical fertilizer development program. Moreover, TVA was especially interested in the limestone geology of the Florence area, since the same underlying geologic conditions existed in many localities in the TVA region. If land application could be accomplished on the Florence site without contamination of the groundwater, the same technique might be transferable to other areas in the Tennessee Valley with similar geologic conditions.

In mid-1978, Florence and TVA entered into a five year cooperative project to test land application on a 173 acre site owned by the city. On a five-and-one-half acre demonstration plot, liquid sludge is being applied under carefully controlled circumstances that are monitored by TVA specialists. Several smaller research plots have been established by TVA agricultural and fertilizer development specialists in order to compare the respective effects of sludge, farm manure and chemical fertilizer on plant growth. Sludge application rates on the test sites vary from 25 dry tons per acre per year, to no sludge whatsoever. Monitoring of nutrient and heavy metal uptake is being evaluated for such crops as Bermuda grass, hay, corn, soybeans and cotton. On all of the sites, groundwater and surface water conditions are being carefully assessed.

The test program won't be completed until 1983, but the early results are promising—something that has not gone unnoticed by area farmers. Says the manager of the Florence municipal sewage commission: "The local agricultural agent and I have farmers calling every day to try sludge on their fields as soon as it is available. If it were approved today, I'd have 10,000 acres for land disposal sites."

Appendix I

Suggestions for Further Reading

Many of the following reports were prepared by or for the U.S. Environmental Protection Agency and can be purchased from:
U.S. Department of Commerce
National Technical Information Science
5282 Port Royal Road
Springfield, Virginia 22151
Telephone: 703/487-4650

In ordering, refer to the title and the report number. Reports not prepared by or for EPA can be obtained from the addresses noted.

Less Technical

Knezek, Bernard D. and Robert H. Miller. (eds), **Application of Sludges and Wastewaters on Agricultural Land: A Planning and Educational Guide**, Report #MCD-35, March, 1978, (Prepared for the U.S. Environmental Protection Agency, Office of Water Program Operations, March, 1978), 93 pp. (NTIS Order No. PB 284824/ AS)

Sludge Recycling for Agricultural Use, (Illustrated Brochure). 1982, 20 pp. SIMPAC, 203 W. Main Street, Collinsville, IL 62234.

More Technical

Council for Agricultural Science and Technology, **Application of Sewage Sludge to Cropland: Appraisal of Potential Hazards of the Heavy Metals to Plants and Animals**, Report #MCD-33, EPA 430/9-76-013. (Prepared for the U.S. Environmental Protection Agency, Office of Water Program Operations, November, 1976), 63 pp. (NTIS Order No. 264015/AS)

Environmental Research Information Center, **Sludge Treatment and Disposal**, Volume 2, **Sludge Disposal**, EPA-625/4-78-012b, October, 1978, 155 pp. (NTIS Order No. 299594/2BE)

U.S. Environmental Protection Agency, U.S. Food and Drug Administration and U.S. Department of Agriculture, **Land Application of Municipal Sewage Sludge for the Production of Fruits and Vegetables: A Statement of Federal Policy and Guidance**, 1981, 21 pp. (Available free from: U.S. EPA, Publications (WH-562), 401 M Street, SW, Washington, DC 20460)

Appendix 2

State Guidelines on Land Application

U.S. Environmental Protection Agency, Office of Water Program Operations, **A Guide to Regulations and Guidance for the Utilization and Disposal of Municipal Sewage Sludge**, Report #MCD-72, EPA 430/9-80-015. September, 1980, 48 pp. (NTIS Order No. PB 81108508)

U.S. Environmental Protection Agency, Office of Water Program Operations, **Municipal Sludge Management: Environmental Factors**, Report #MCD-28, EPA 430/9-77-004. October, 1977, 130 pp.

Sopper, W. E., E. M. Seaker, and R. K. Bastian. (eds), **Land Reclamation and Biomass Production with Municipal Wastewater and Sludge.** 1982, 535 pp. The Pennsylvania State University Press, 215 Wagner Building, University Park, PA 16802.

Robson, C. M. and L. E. Sommers, **Spreading Lagooned Sewage Sludge on Farmland: A Case History**. EPA 600/52-82-019. May, 1982. (NTIS Order No. PB 82-181 082).

Miller, R. **The Ohio Farm Bureau Demonstration and Research Project on Land Application of Municipal Sewage Sludges.** IN: Proceedings of the 1979 Annual Conference of Applied Research and Practices on Municipal and Industrial Waste. September, 1979. University of Wisconsin, Madison, WI 53706.

Several states have established their own guidelines on land application of sludge. The following references provide citations to such guidelines in selected states. Although the listing is not comprehensive, it should be useful to conservation districts and others, even in states that are not identified.

Colorado
Department of Health, Water Quality Control Commission
Guidelines for Sludge Utilization on Land
1978

Illinois
Environmental Protection Agency
Technical Policy WPC-3
Design for Criteria for Municipal Sludge Utilization on Agricultural Land
April, 1977

Maryland
Department of Health and Mental Hygiene
Code of Maryland Regulations 10.03.48
Uses and Methods of Collecting, Handling, Burning, Storage or Transportation of Sewage Sludge
1980

Michigan
Department of Natural Resources
Water Resources Commission
General Rules R 323.2201 to R 323.2211
May, 1978

Minnesota
Minnesota Pollution Control Agency
Recommendations for Application of Municipal Wasterwater Sludges on Land
August, 1978

New Jersey
Department of Environmental Protection
Division of Water Resources
Guidelines for the Preparation of Sludge Management Plans (Draft, 1979)

Ohio
Cooperative Extension Service
Ohio State University
Ohio Guide for Land Application of Sewage Sludge, Bulletin 598 (revised)
June, 1979

Oregon
Department of Environmental Quality
Guidelines for Land Application of Wastewater and Sludge
May, 1981

Pennsylvania
Department of Environmental Resources
Interim Guidelines for Sewage Sludge Use for Land Reclamation
Solid Waste Rules and Regulations, Chapter 75, Subchapter C, Section 75.32
1978

Wisconsin
Department of Natural Resources
Guidelines for the Application of Wastewater Sludge to Agricultural Land
Technical Bulletin #88
1975

☆ U.S. Government Printing Office : 1982 – 388-462/265

United States
Environmental Protection
Agency

Office of Water
Program Operations (WH-547)
Washington DC 20460