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Proper disposal of sewage sludge is a growing problem for many communities in Indiana. Sewage sludge, very simply, is the by-product of waste water treatment.

Indiana and federal laws require that sewage effluent be treated before it is returned to steams or rivers. Presently, the most common method of handling raw sewage (at least in communities of 3,000 population and above) is through sewage plants that employ a two- or three-step treatment process. Primary treatment removes most of the solids by settling; secondary treatment continues to break down the partially-clarified sewage by aerobic digestion; and in some cases, a tertiary treatment with chemicals further removes any solids remaining in solution. The material left at the end of these processes is what we call "sludge," which must be disposed of in some way.

There are numerous methods of disposing of sewage sludge. Some of the more common ones (and their approximate costs) include: (1) dewatering through additional heat, then marketing as a fertilizer* — $73 per ton; (2) dewatering and incinerating — $69 per ton; (3) continuous digestion in a permanent lagoon — $54 per ton; and (4) digesting then applying on land — $16.50 per ton.

Needless to say, land application as an alternative disposal method is receiving considerable attention today, not only from community officials, but also from agricultural producers who can benefit by accepting sludge on their cropland.

The purpose of this publication, therefore, is to acquaint both community leaders and agricultural producers with cropland application of sewage sludge — what it is and how it works, its advantages and drawbacks, and the factors that determine when, where and how much can be applied. Also provided is a list of related publications and sources of assistance in the area of waste treatment and disposal.

*An example of this is a product called "Milorganite," sold at numerous nurseries.

HOW CROPLAND APPLICATION WORKS

Cropland application of sewage sludge is not new in Indiana. Some communities have been using this method of disposal for years. It is true that, in some of these cases, the way in which the sludge was applied has not been in the best interest of soil productivity and environmental quality. Simply dumping large amounts of sludge on land is poor use of both the sludge resource and soil resource. But where proper disposal rates and techniques are followed, and where a spirit of cooperation between municipal government and the agricultural producer prevails, this system has worked well.

Several methods of land spreading can and are being used. Probably the most common is hauling the sludge from the digesters or storage lagoons in tank trucks and surface-spreading on fields when they (the fields) can support traffic. The feasibility of this method is largely determined by the distance hauled. Some communities are injecting the sludge into the soil rather than surface-spreading, because of complaints about odors; but it should be mentioned that properly-digested sludge does not have a particularly offensive odor. Injection, of course, increases the cost somewhat.

Another way to land-apply is to pump the liquid sludge from treatment plant to disposal area and irrigate through gated pipes. Success of this system depends on the proximity, topography and soil properties of the disposal site. Pilot studies are presently underway in Illinois in which liquid sludge is being irrigated onto both cropland and recently-disturbed strip-mine land by "big-gun" sprinklers.

Because these and other land application systems are still relatively new and not fully tested, it's impossible at this time to say which one is best and under what conditions. However, we do know that, where land spreading is being used, the municipal government has stood the full cost of transporting and spreading the sludge, while in most cases, the producer has had only to agree to accept the material. Of course, the exact arrangement will vary from community to community.

ADVANTAGES OF CROPLAND APPLICATION

1. Cropland utilizes the nutrients in sewage sludge. Sludge contains many elements for plant growth, such as nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, copper, iron and boron. Returning these nutrients to the soil — where they are first taken up by plants then fed to animals, man or used in industrial processes — is recycling in the best sense. The soil-plant-animal system not only makes effective use of the nutrients in sludge, but also takes them out of the pollution picture. This is especially important in the case of nitrogen and phosphorus, which can adversely affect water quality.

2. Cropland benefits from the organic matter in sewage sludge. This material, if readily decomposable when applied, can improve soil structure (aggregation and porosity) and increase its water-holding and nutrient-holding capacities. The ability of sludge organic matter to "trap" and hold plant growth elements is about 40 to 50 times greater than that of course-textured soil with low organic matter content. Therefore, adding organic waste to such a soil can substantially improve its nutrient-holding capacity and thus its productivity.

3. Soil filters sewage sludge to minimize pollution potential. Soil has tremendous capacity to decompose organic wastes. Research shows that an acre of land can biodegrade or "digest" as much as 300 pounds of B.O.D.* per day during the growing season. That would mean 112 pounds of sludge organic carbon. Most of the bacteria and other disease-producing organisms in sludge die in the soil, because it's a hostile environment to them. In fact, a Wisconsin study found that 98 percent of the bacteria in livestock manure applied to a silt loam soil was filtered out in the top 14 inches.

Soil also serves to inactivate the phosphorus in sludge, thereby keeping it out of the groundwater. When added to soil, phosphorus quickly combines with other elements to become water insoluble. This is illustrated by the fact that 10 to 30 percent of fertilizer phosphorus is recovered by this first crop; the rest is held in the soil.

*Biochemical Oxygen Demand, which is a measure of the oxidizable organic material contained in waste.

4. Cropland disposal of sewage sludge is economical. Compared to the other methods of disposal, applying sludge to the land is significantly less expensive — in some cases, only about one-fifth as much, making it very attractive to community officials. The degree of economic advantage, however, depends on the pumping or hauling distance.

The fact that sludge material provides the soil-building and fertilization benefits mentioned above is a further bonus to the one receiving the sludge, since in many cases the transport and distribution costs are borne by the city. With the possibility of shortages and the certainty of increased cost of fertilizer material, accepting sludge on their cropland is becoming an ever more inviting alternative to farmers.

FACTORS AFFECTING DISPOSAL — 1. SLUDGE COMPOSITION

The composition of sewage sludge is highly variable and depends on such things as the number and types of industries in the community, efficiency and size of the treatment plant, etc. Generally, however, liquid sewage sludge contains from 1 to 10 percent solids. That solid fraction is composed of approximately equal amounts of inorganic and organic material. The inorganic portion contains a large number of elements, mainly metals; while the organic portion is a complex mixture of degraded sewage constituents, compounds synthesized by microbes during digestion, dead and live microbial cells, and contains organic carbon, nitrogen, phosphorus and sulfur. (See Table 1.)

When, where and how much sewage sludge can be applied to cropland is determined, in part, by its composition. Nitrogen content, salt and heavy metal concentrations, organic matter content and organisms present all impose potential limitations to land disposal of sludge. Following is a discussion of each, with these limitations underscored.

Table 1. Average Chemical Composition of Sewage Sludge from Ten Indiana Cities.

Element	Concentration	Element	Concentration
	pct.		ppm
Total N	4.9	Zinc	8100
Ammonium N	2.1	Manganese	750
Phosphorus	2.4	Copper	2800
Potassium	0.4	Cadmium	170
Sodium	0.8	Lead	770
Calcium	7.9	Mercury	4
Magnesium	1.2	Chromium	4300
Sulfur	1.0		

Source: See reference No. 3 under Related Publication.

Nitrogen Content

The major factor affecting land application of sewage sludge in this part of the United States is nitrogen content. The concern over nitrogen is threefold: (a) an excessive amount of the nitrate form of nitrogen in drinking water is harmful to animals and humans; (b) excessive nitrates in the soil can create high levels in animal feed, thus leading to animal health problems; and (c) nitrates in lakes and rivers stimulate growth of algae, which can eventually cause eutrophication (advanced aging) of a body of water.

About 1/2 to 2/3 of the nitrogen in sludge is tied up in an organic form and only slowly available to plants. The remaining 1/3 to 1/2 is largely in the ammonia form and readily available for plant use. While in the ammonia form, the nitrogen is not subject to leaching. But when applied to the land during late spring, summer and fall, it is rapidly changed to the nitrate form, which moves with water through the soil and, if present in excessive amounts, can pollute the ground water.

How fast sludge nitrogen is released depends on the rate of organic matter decomposition. Generally, it is much slower than the release of animal waste nitrogen — probably about 10 or 20 percent the first year compared to 50 or 60 percent for animal waste nitrogen. Nevertheless, the amount of sewage sludge applied to the land should be limited to the extent that the nitrates formed cannot build up to levels that could adversely affect ground water quality.

Salt Concentrations

Sludge high in salts (particularly sodium), if applied heavily, can cause soils to puddle and thus greatly reduce water intake. High concentrations at the soil surface can also retard seed germination and plant growth. Salt problems are more likely to occur from sludge heavily loaded with industrial waste than from other types.

Heavy Metal Concentrations

"Heavy metals" include such elements as iron, zinc, lead, copper, mercury, nickel, chromium and cadmium. Exactly to what extent these materials affect plant growth and water quality is not clear at present; but much research is underway in this area. Certain heavy metals, such as iron, zinc and copper, are essential to plant growth but are needed in only small amounts. Problems arise when they occur in excess.

It is known, however, that heavy metals in sewage sludge are largely tied up with organic matter in insoluble forms and are, therefore, taken up only very slowly by plants. Just how much is taken up and how rapidly depends on both application rate (high rates may result in immediate toxicity) and rate of breakdown of the organic matter, which, in turn, is determined by sludge composition, climate and soil reaction at the disposal site (e.g., acid soils increase the solubility of heavy metals). One European study showed that it took 50 years before sludge applied to the land caused a plant growth problem.

Sludge will vary in heavy metal composition, depending on the type and amount of industrial waste going through the treatment plant at any one time. Therefore, it is important to know sludge content and how it might vary during the year, before applying it to the land.

Organic Matter Content

Some sewage sludge contains organic materials, such as waxes, oils, etc., that break down very slowly. If applied in heavy amounts, such material can act as a water barrier and temporarily prevent water from entering the soil. Therefore, some sludges should be allowed to dry before applying more. This allows it to shrink, thus breaking the barrier that would keep water out.

There is also evidence that overloading the soil with slowly-decomposing, partially inert material can temporarily reduce the soil's productivity.

Organisms Present

Sewage sludge may contain certain disease-producing viruses and bacteria. While some organisms would pose a real threat in raw sewage, they shouldn't create disease problems in anaerobically-digested sludge — i.e., sludge having received primary and secondary sewage treatment and stored several days in an anaerobic lagoon. However, even anaerobic sludge should not be applied to leafy vegetables or to shallow-rooted root crops near harvest time.

FACTORS AFFECTING DISPOSAL — 2. THE SOIL

Amount, time and method of sludge disposal on cropland are influenced by the soil at the disposal site as well as by composition of the sludge. Soil properties that must be considered include: water intake rate, location of water table, topography, water-holding capacity and nutrient-holding capacity.

The "ideal" soil in a disposal area would be one that: (a) has a high water intake rate; (b) is deep and not excessively permeable to water table for good filtering; (c) is nearly level to minimize runoff and erosion; (d) is in an upland area at least several hundred feet from a water course, with no danger of flooding or runoff to a stream; (e) has high water-holding capacity; and (f) has high nutrient-holding capacity. (The latter two properties determine a soil's ability to remove sludge nutrients and retain them for recycling through crops.)

Chances of finding the perfect soil at any potential disposal site, however, are rather remote. Therefore, accurate soils information is a must — first of all, to select the *most trouble-free* disposal area and, secondly, to properly adjust the application method, rate and time to compensate for these less-than-ideal soil properties.

For example, crops grown on droughty, low yield-potential soils remove less nitrogen than ones grown on high yield soils. This reduces the amount of sewage sludge these poorer soils can handle without danger of nitrate contamination to ground water. Rate of sludge application to coarse (very sandy) soils must also be reduced and carefully monitored, since such soils possess little filtering capacity and water moves rapidly through them.

Waste disposal by spray irrigation is not recommended on soils with very slow internal drainage and intake rates; unequal application would likely occur due to runoff from high areas and ponding at low spots. A subsurface injection system would work much better on such soils.

FACTORS AFFECTING DISPOSAL — 3. THE CROP

Cropland disposal of sewage sludge is based on the recycling of nutrients through growing plants then harvesting the plants. Most research confirms that where crops are actively growing, nitrates from either fertilizer, manure or sludge applied in moderate amounts do not get into the ground water.

Almost any type of crop can be grown at a disposal site, although some will utilize more nitrogen than others. Purdue studies found that, under top management, grasses such as reed canary, orchard and fescue remove as much as 300 pounds of nitrogen per acre per year; sudax removes over 550 pounds per year; and a 150-bushel corn crop takes off up to 200 pounds when harvested for silage or when stalks are removed.

Regardless of the crop grown, the key to avoiding ground water pollution by nitrates is to insure that the amount of nitrogen released by the sludge does not greatly exceed the amount utilized by the crop. Therefore, where climate or soils limit yields, additional land area will be required for safe sludge disposal. Table 2, which shows amount of nitrogen removed by various crops, can serve as a guide for determining total acres needed for the volume of sludge to be applied.

Table 2. Nitrogen Removal by Crops.

Crop	Yield per acre	Lbs. of N removed per year
Corn (grain only)	100 bu.	90
	150 bu.	135
Corn silage	16 ton	160
	25 ton	200
Wheat (straw not removed)	40 bu.	50
	60 bu.	100
Wheat (straw removed)	40 bu.	70
	60 bu.	125
Grasses (Reed canary, tall fescue, orchard, brome)	3-4 ton	160
	6-8 ton	300

Successful land application of sewage sludge also means proper management of the crop at the disposal site. Here are three practices that should be followed:

1. Provide vegetative cover on the soil surface during as much of the calendar year as possible. This protects the soil from sealing, thus maintaining a high water intake rate.

2. Keep an actively-growing crop on the land as much of the disposal year as possible. A growing crop makes maximum use of the nutrients and water in wastes. Consider a rotation of grasses or sods for early spring and late fall, and row crops during the regular growing season. Sludge can be applied to row crops in late spring and summer through an irrigation system.

3. Harvest the crops and remove them from the disposal area to take full advantage of nutrient recycling.

WHERE TO GO FROM HERE

"Is cropland application of sewage sludge a feasible and beneficial alternative in our situation?" The answer to that question calls for careful evaluation of your community's present and anticipated waste disposal problems, the types of waste involved and the potential sites for disposal in light of the principles we have discussed in this publication.

Here, in summary, are the requirements for a successful land disposal operation:

1. Know the composition of the sludge as to its nitrogen content, salt and heavy metal concentrations, organic matter content and presence of disease organisms.

2. If heavy metal and/or soluble salt concentrations are high, determine, if possible, what effect they might have on soil properties, on water quality, on plant growth and composition, and on animals or people if the plants are consumed.

3. If the sludge contains potentially harmful bacteria and/or viruses, make sure no material is applied to leafy vegetables or shallow root crops. Sludge applied and worked into the soil before seeding should not contaminate such crops.

4. Know the soil at the disposal site, and be familiar with those properties that might affect time, method and rate of application. Although soil is an excellent filtering medium, it does have limitations. Don't overload its capacity to do an effective job.

5. Apply sludge to the land at a "reasonable" rate. This means at a rate such that the amount of sludge nutrients put on does not greatly exceed what the disposal site crop can take off. Use crop requirement figures for nitrogen as a guide (Table 2). In sewage sludge, readily-available nitrogen usually makes up 1/3 to 1/2 of the total nitrogen. If at the rate calculated for the proper nitrogen level it is found that either copper, zinc or nickel levels are excessive, reduce the sludge application rate accordingly, then make a fertilizer application of supplemental nitrogen to meet the needs of the crop.

RELATED PUBLICATIONS

For assistance with sewage sludge disposal problems, contact your local County Extension Office. The following related publications may also be of help but are in limited supply. Contact J. V. Mannering, Agronomy Department, Purdue University, West Lafayette, Indiana 47907, for these materials.

1. "Utilization of Urban Wastes in Crop Production," C. W. Carlson and J. D. Menzies. *Bio Science,* Vol. 21, No. 12, pp. 561-564, 1971.

2. "Effects on Corn by Applications of Heated Anaerobically-Digested Sludge," T. D. Hinesly, R. L. Jones, and E. L. Ziegler. *Compost Science,* pp. 26-30, July-Aug., 1972.

3. "Chemical Composition of Sewage Sludge from Selected Indiana Cities;" L. E. Sommers, D. W. Nelson, J. E. Yahner and J. V. Mannering. *Proceedings of the Indiana Academy of Science,* Vol. 82, pp. 424-432, 1973.

4. "Land Disposal of Waste Water and Sewage Sludge," L. E. Sommers and D. W. Nelson, Agronomy Department Mimeo, Purdue University, 1973.

5. "Recycling Municipal Sludges and Effluent on Land," Conference Proceedings. Sponsored by U.S. Environmental Protection Agency, U.S. Dept. of Agri., and Nat. Assn. of State Univ. & Land Grant Col., July 9-13, 1973, Champaign, Ill.

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