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Land Treatment of Sewage Effluent in Florida [1]

Allen R. Overman[2]

Abstract

During the last 20 years, land application has gained acceptance as an alternative method for sewage treatment. Experience from research and operational systems provide guidance in crop selection and soil investigation for site evaluation. Various factors important to successful operation are discussed.

Introduction

This article is intended as an overview of land application in Florida, particularly for persons called upon for technical advice on some aspect of the subject. It does not deal with details of site evaluation and system design, since these are covered in technical manuals and bulletins used by practitioners in the field.

Attention on land application has intensified since passage of the 1972 Federal Clean Water Act, PL 92-500, and subsequent amendments of 1977. As a part of the effort to clean up the nation's surface waters, this legislation placed greater emphasis on resource recovery and recycling. Financial incentives were provided by making land purchased for lant treatment eligible for federal grant funds. In the 1977 amendments waste treatment technology classified as innovative or alternative became eligible for 85% federal construction grant funds administered by the U.S. Environmental Protection Agency. In the general design process, land application is evaluated as one of several treatment alternatives.

Land application is being used at several locations in Florida. Field experiments were begun in Tallahassee in the early 1960's and expanded in the 1970's. These clearly demonstrated the potential for wastewater renovation and crop production when properly designed and managed. Municipal waste treatment is governed in Florida by the Department of Environmental Regulation through Rule 17-6. A section of this rule provides land application guidelines. The position of the agency appears to neither encourage nor discourage land treatment, but simply to regulate the practice as required by Florida Statutes.

Methods of Land Application

Early land disposal practice was direct application of raw sewage to land. This frequently led to ponding and odor problems. Soil clogging led

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2. Allen R. Overman, professor, Agricultural Engineering Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

to extended ponding and difficulties with field man agement. Modern land treatment usually involves preapplication biological treatment of waste. In Florida this means either a trickling filter or an activated sludge unit.

At present, EPA recognizes three modes of land treatment: (1) slow rate irrigation, (2) overland flow and (3) high rate infiltration. Each of these will be described briefly. Application rates will be given in inches per week, similar to rainfall values.

Two tables are included here to aid in field design. Table 1 provides estimates of field area required in relationship to treatment plant flow and irrigation rate. For example, at 1 million gallons per day (mgd) and 2 inches per week, a field area of 130 acres is required. Table 2 shows the influence of concentration and irrigation rate on nutrient loading. For example, for a wastewater with a total nitrogen concentration of 20 milligrams per liter (mg/l) and an irrigation rate of 2 inches per week, a nitrogen loading rate of 480 pounds per acre per year is obtained. Similarly, for a total phosphorus concentration of 10 milligrams per liter and an irrigation rate of 2 inches per week, phosphorus loading amounts to 240 pounds per acre per year.

Slow Rate Irrigation

This method involves irrigation for crop production. The effluent may be applied by either surface or sprinkler techniques. Typical application rates are 1 to 4 inches per week. Corresponding nitrogen loading rates are 100 to 1000 pounds per acre per year. Nutrient loading depends upon both irrigation rate and nutrient concentration in the effluent. A typical nitrogen concentration for domestic effluent is 20 milligrams per liter. Loading rate is determined by hydraulic capacity of the field and nutrient uptake by the crops. These systems are designed for percolation of the applied water and removal of sufficient nutrients (usually nitrogen) to meet water quality standards. A number of projects are now in operation using this method.

Overland Flow

This method is used on soils with low infiltration capacity and high runoff potential, due either to high clay content or restrictive layers (clay or organic). Typical application rates are 2 to 16 inches per week. The crop covers in this case serve to stabilize the soil and provide a biological filter. In some cases the vegetation may be used for animal feed. While some crop uptake of nitrogen occurs, the system is usually managed to achieve biological reduction of nitrogen and carbon. Since there is surface discharge, water quality criteria of the receiving stream must be met. Field studies are presently underway to evaluate operational aspects of this method in Florida.

High Rate Infiltration

This method requires a high hydraulic capacity. Application rates are usually 1 to 10 inches per day. Vegetation is usually not included in these systems. Since suspended solids are filtered out at the soil surface, gradual clogging occurs. This requires a drying period for restoration of the infiltration capacity. This periodic flooding and drying requires -that two or more basins be utilized. Since complete percolation occurs the system must meet groundwater quality criteria. Limited experiments have been conducted, but the method is generally not used in Florida. It does offer a significant cost advantage in initial capital cost and in operation. This approach should not be confused with percolation ("perc") ponds, which are not managed by periodic flooding and drying, and frequently lead to overflow.

Methods of Water Application

Two general types of distribution methods are used: (1) sprinkler and (2) gravity. Sprinklers may be used under a variety of conditions while the gravity method is suitable only with shallow water table soils with a restrictive layer in the subsoil.

Sprinklers

This method is most commonly used for effluent irrigation in Florida. A wide variety of sprinkler configurations are used, depending upon field configuration, type of vegetation and effluent characteristics.

Fixed. - These units are underground distribution pipes with fixed risers. Sprinkler heads are usually the rotating impact type. Spacings typically range from 60 to 300 feet, with nozzles sizes from 1/4 to 1 3/4, inches. Larger nozzles require fewer risers and exhibit less clogging, but require considerably greater pumping energy. Units of this type are used rather extensively in Florida for irrigation and for land treatment systems as well.

Traveling Gun. - Water may also be distributed with a sprinkler head mounted on a traveling unit with water supplied through flexible hose. Nozzle size is usually in the range of 1 to 1 3/4 inches. This approach has the advantage that a single unit may be used to cover a larger area. The disadvantage is the greater labor requirement, even with increased mechanization of system management. Traveling guns are used extensively in Florida irrigation.

Center Pivot. - The need for mechanized irrigation systems led to development of center pivot units. In this case the water distribution pipe is pivoted at one end and nozzles are mounted along the pipe. Support towers are typically spaced approximately 100 feet apart. Early units were designed to cover 160 acres, but much longer units are available today. Drive mechanisms may be either electric motor or internal combustion engine. These systems are cyclic by nature and have a low labor requirement. Manufacturers have developed low pressure nozzles to reduce energy consumption and corner units to more fully utilize the field area. A large number of center pivot units are now in operation in Florida.

Lateral Move. - These units are used on relatively flat topography. Water is pumped from a canal through a moving lateral distribution line. Nozzles are spaced uniformly along the line. Drive mechanisms are either electric or hydraulic. Water is usually pumped with a diesel engine. The advantage is the use of uniform nozzles, while the disadvantages are the need for rectangular fields and greater management of engines over electric motors. Lateral move systems are in limited use in Florida.

Gravity

This approach requires flat topography and a restrictive soil layer. Seepage irrigation is used extensively in Florida in range pastures and vegetable fields. The advantage is the low energy requirement compared to sprinklers. However, the soils require extensive drainage during high rainfall. This would complicate effluent irrigation in these areas, and would necessitate sizeable storage volume. Discharge water must meet water quality criteria of the receiving stream.

Evaluation of Sites

A number of characteristics are important to design and operation of a land treatment system. These influence which mode to use, selection of vegetation and operation of the system. While design of these systems is site specific, a number of common factors should be considered.

Field Configuration

This feature should be considered both in site selection and system design. A combination of several small irregular parcels may present difficulties in layout of distribution network. Conversely, a nearly square or circular field would be more suitable for a center pivot unit. Topography should also be considered, particularly where there are low lying areas that may periodically collect runoff and cause ponding.

Vegetation

Both existing and planned vegetation must be considered. In some cases existing vegetation may be suitable for land treatment. Where land clearing is necessary, this figures into the cost of the project and requires attention to specifications to insure a field suitable for crop production. Selection of vegetation is determined by the treatment mode and utilization of the crop. Crops for direct human consumption are generally excluded. Both field and forage crops have proven satisfactory. Both yields and nutrient uptake are considered in the design.

Physical Properties

Field investigation usually covers several physical properties, since these determine suitability of a specific site and the mode of treatment. Failure to give adequate attention to this aspect can lead to failure or low performance of the system.

Soil Features. -These usually include depth to water table, drainage class, soil type and classification, presence of restrictive layers, and permeability. Frequently clay or organic layers are present which control percolation of water through the soil profile. The soil may become saturated during rainfall or irrigation, causing runoff and limiting plant roots. In some cased field modifications, such as land grading, surface drainage or subsurface drainage, is required to achieve adequate performance. Field properties also influence the level of floatation required for equipment such as tractors and harvesters. Irrigation schedules and storage volume must take these into account, as well.

Geological Features. - Depths to aquifers, direction and velocity of groundwater flow and transmissibility are usually determined. Overland flow exerts the least influence on groundwater of the three modes- Extensive field borings are made to estimate the impact of land application on groundwater quality.

Chemical Properties

Determinations are made of pH, cation exchange capacity and groundwater quality. In many cases it is necessary to apply lime to raise the pH to the optimal range of 5.5 to 6.5 for crop production.

Composition of the limerock may also be determined in relation to chemical stability.

Selection of Vegetation

Several types of vegetation have proven suitable for land treatment in Florida. The same factors should be considered as with standard agriculture. For land treatment additional consideration is given to irrigation and drainage aspects. The added water can cause problems with water management and can also interfere with field operations such as harvesting.

Treatment Mode

The type of vegetation to be used is greatly influenced by the mode of land treatment employed. For high rate infiltration, no vegetation is generally required. Overland flow systems use grasses which provide good ground coverage and will tolerate wet conditions. Slow rate irrigation systems use forage crops, field crops, turf grasses and trees. It is important to use crops adapted to the climate and soil conditions at the site.

Vegetation

Forage Crops. - Field experience has shown that several forage crops can be used in land treatment systems in Florida. Crop uses include hay, greenchop, silage, haylage, pelleting and pasture. Consideration should be given to weather, field conditions and crop utilization. For example, summer rains make it diff difficult to consistently harvest high quality hay in Florida. Market prices for hay fluctuate widely, also. Due to the high moisture content and cost of hauling, greenchop production requires that an animal feedlot be located in close proximity to the site. Both silage and haylage require extensive storage facilities, which should be accounted for in the design of the system. Pelleting produces a sellable product, but represents high energy consumption. A pasture operation requires the lowest capital cost and management input. However, in some cases surface runoff may occur and lead to water quality problems. The design process must weigh these considerations carefully. Most systems include a winter cover crop such as rye or ryegrass.

Field Crops. - Grain crops such as corn and sorghum have been used. Allowances must be made for drying time before harvest. For field corn that is to be processed through a grain dryer, a period of 3 or 4 weeks without irrigation just prior to harvest would be desirable. This would require either staging of the field operations or extended water storage. For high moisture grain down time could be shortened, but oxygen-free storage facilities for the crop may be required.

Turf. - Effluent has also been applied to turfgrasses, such as golf courses and lawns. In these systems the main consideration is application rate for irrigation purposes. Beneficial effects of the nutrients is usually a secondary consideration.

Trees. - Several species of trees have been shown to respond favorably to effluent irrigation. In these systems particular attention should be given to water distribution and harvest practices. On flatwoods soils gravity irrigation might be utilized. Cyclic application should be used to minimize odor and insect potential.

Summary

This article has covered some of the factors which should be considered in design and operation of land application systems in Florida. A number of physical, chemical and biological components and processes are involved. The design engineer must give attention to each of these and particularly to interactive effects, such as loading rate and water quality (groundwater and surface water. Field experience has shown that land treatment systems can be designed and operated to achieve wastewater renovation and crop production. Experiments are continuing to provide additional information on the basic processes and guidance in practical operation.

Table 1.

Table 1. Field Area Required for Land Treatment.				
Field Area (Acres)				
Flow (MGD)	Irrigation Rate (inches/Week)			
	1	2	4	8
0.1	26	13	6.5	3.2
1	260	130	65	32
10	2600	1300	650	320

Table 2.

Table 2. Nutrient Loading for Land Treatment Nutrient Loading (Pounds/Acre/Year).				
Conc. (Mg/L)	Irrigation Rate (inches/Week)			
	1	2	3	4
1	12	24	36	48
5	60	120	180	240
10	120	240	360	480
20	240	480	720	960
50	600	1200	1800	2400