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Research Needs for Evaluating Land Treatment of Municipal Wastewater

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ABSTRACT

Land treatment of municipal wastewater is receiving increased attention as a wastewater management alternative. Additional research is needed to answer economic and institutional questions surrounding its use. Research issues were categorized into system design consideration and the impacts of land treatment systems.

Water pollution has been and continues to be a significant environmental and economic problem for communities of all sizes in the United States. A major source is effluent from domestic and industrial wastes which is directly or indirectly discharged into streams, rivers, and groundwater supplies.

Federal and state laws were passed to reduce water pollution. The 1972 Amendments to the Federal Water Pollution Control Act, Public Law 92-500, require all publicly owned treatment plants to process their wastewater to the level of secondary treatment by July 1, 1977. Zero discharge of pollutants to navigable waters by 1985 has been set as a national wastewater management goal.

Communities faced with meeting the legal requirements for wastewater treatment will closely evaluate alternative treatment methods to determine the most cost-effective method to provide secondary and tertiary treatment. The basic alternatives for advanced wastewater treatment are land treatment, advanced biological treatment, and physical-chemical treatment. The land

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alternative is receiving increased attention because of specific provisions in the Water Pollution Control Act Amendments of 1972. These are the first federal laws that specifically encourage land treatment and authorize federal construction grants to state and local agencies to assist in the establishment of such systems. Subsection 201(d) of the 1972 Amendments encourages wastewater treatment which results in the construction of revenue producing facilities providing for: (1) the recycling of potential sewage pollutants through agricultural and forestry production; (2) the reclamation of wastewater; and (3) the ultimate disposal of sludges in a manner not harmful to the environment. Waste treatment management is encouraged that combines open space and recreational considerations, and that integrates facilities for sewage treatment and recycling to treat, dispose of, or utilize other industrial and municipal wastes.

Land treatment refers to the application of wastewater and sludges to land. Generally it is materials from municipal and industrial sources that have received primary and secondary sewage treatment prior to its application. The soil and agricultural crops or forests then adsorb and filter nitrates, phosphates, and other elements from the effluent and sludge. The remaining "purified" water drains through the soil to recharge the groundwater or to return via underdrains to a water course. Data on the "living filter" concept has been collected at The Pennsylvania State University since 1963 (Kardos). Muskegon County, Michigan has received national attention for its wastewater irrigation project, where a land treatment system will eventually treat the industrial and municipal wastewater from approximately 160,000 people (Bauer). Several communities in the southweastern United States have operated land disposal systems for 40 years. San Angelo, Texas started wastewater irrigation in 1933 while Bakersfield, California began in 1939 (Sullivan).

This report will identify several areas for additional economic research related to land application of wastewater. Potential research topics range from specific system considerations to broad regional and national effects. Table 1 lists research priorities identified at four workshops on the economics of land treatment of wastewater, and serves as a departure point for suggestions for additional research.

System Design Consideration

Technical and economic issues related to the establishment and operation of a land treatment system include: system selection and costs, land acquisition, financing, crop selection and marketing.

Issue: System Selection

Wastewater can be applied to land through three basic methods: irrigation, overland flow, and rapid infiltration (Pound and Crites). Each method has its unique characteristics to be tailored to the particular situation. Irrigation is the controlled discharge of effluent, by spraying or surface spreading, on land to support plant growth through infiltration and percolation within the boundaries of the disposal site. Overland flow is the controlled discharge on land with downslope sheet flow over impermeable subsoils. It is particularly useful where low soil permeability prevents wastewater from penetrating or moving through the soil profile. Rapid infiltration is the spreading of liquid on land with high rate infiltration and percolation of the effluent into the soils.

Table 1. Economic issues raised during four workshops on land application of wastewater.*

TOPIC	URBANA	ATLANTA	CHICAGO	HARRIS-BURG
Consideration of the total system	VH**	VH	H	N
Data collection	H		H	
Production relationships	VH			
Risk evaluation	H	N		N
Sensitivity analysis	H			
Cost effectiveness of land treatment with differences in land quality, site location, distance, and climate	VH	VH	N	VH
Management problems (system monitoring can be traded off against site preparation)	H			
Land ownership vs. leasing	H	H		VH
Incentives to use land treatment (cost sharing taxation community grants, pricing of services, and payment options)	VH	N	H	H
Regional and community effects	VH		VH	VH
Community size (economies of scale)	VH	H		
Storage and winter application	VH			N
Applying raw or partially treated wastes	H			
User charges		VH		N
Product marketing		VH		VH
Minimize energy requirements				H
Feasibility of using land treatment for purposes other than crop production (reclaiming land, salt water intrusion)				H
Value of wastewater treatment				N

*Sources: Stucky, North, Miller, Frey

**Priority ranking: VH = very high, H = high, N = normal

Unlike irrigation, this system is primarily a waste treatment system designed to handle volumes of wastewater far in excess of irrigation rates.

In their discussion of land treatment costs Pound and Crites state that spray irrigation is the highest cost per unit treatment system followed by overland flow with rapid infiltration the least expensive. Reed indicates that the highest level of renovation occurs with spray irrigation and the least with rapid infiltration.

Issue: System Costs

A model to evaluate land application would include: a cost function for land treatment, a cost function for an alternative treatment method, a crop yield function, a damage function for land treatment, and a damage function for alternative treatment techniques. A model which shows that the marginal cost of alternative treatment technology affects the optimal application rate was developed by Seitz and Swanson. Their model points out the need to maximize profits or net benefits; not total yields or benefits.

A simulation model for land treatment can be developed using either engineering or statistical cost data. Tradeoffs can be made between pumping and transportation costs and land or site impact costs. Higher land prices imply more intensive land use (higher application rates). As wage rates rise one would expect capital to be used more intensively. Higher energy prices encourage the use of land treatment, since it uses relatively less energy[1/] and provides substitute nutrients for higher priced commercial fertilizers. Changes in crop prices, treatment regulations, types of systems, cover crops, and application rates should be evaluated to determine their effect on the entire system.[2/]

The APWA on-site survey (Sullivan) found that 73 percent of the sites serve less than 5 mgd (50,000 people). In the mail survey no community serving over 10 mgd was found. This implies that land application may have advantages for smaller communities. Research is needed to show the impact of community size on the feasibility of land treatment.

Issue: Land Acquisition and Management

Land treatment requires rights to land held by farmers. Alternative options exist for acquiring and managing land treatment systems. Land can be controlled through fee simple ownership, less than fee simple ownership (easements), or contractual agreements (leasing). Management options include purchase and manage, purchase and leaseback, contractual lease agreements, and cooperatives. A recent survey of treatment site ownership (Young and Carlson) found approximately 50 percent of the surveyed sites were privately owned. Costs will vary and influence the institutional options. Site selection and ownership will be determined by land cost, zoning, land use regulations, local residents, local taxing policies, and type and availability of financing. Further research is needed to evaluate acquisition and management options in light of actual system experiences.

Land costs are generally inversely related to proximity to urban centers, but pumping costs increase with distance. The median land value in the APWA survey was $500 per acre (Sullivan), and ranged up to $2000 per acre. The total purchase price of land should not be charged against the project, if it is used for multiple purposes. Only the land costs directly related to wastewater renovation should be included.

Issue: Financing

Wastewater treatment is expensive. Alternatives to pay for capital costs and operating and maintenance costs include sale of bonds, taxation, state and federal grants, sale of effluent and sludge, sale of crops, and pricing of water and sewer services.

If heavy metals are a problem, a surcharge can be used to limit industrial discharge. However the use of a surcharge must be traded off against economies of scale in waste treatment, timing of waste production and industrial employment in the community.

Financial issues will affect the rate of adoption of land treatment. The effect on the local tax base should be analyzed. The Muskegon project makes an annual payment to the taxing authorities based on their property value. Government cost sharing affects design, operation, and management of wastewater treatment facilities. Under the current law, land which is an integral part of the treatment process is eligible for cost sharing but other land is not. A bias may exist for or against land treatment depending upon which process requires more inputs that are eligible for a subsidy--conventional treatment or land treatment. Carlson and Young found that prior to the 1972 Amendments a bias against land treatment existed since land costs were not eligible for subsidies.

Issue: Crop Selection

Pound and Crites list high water tolerance, nutrient uptake, salt tolerance, market value, and management requirements as influencing crop selection. Grasses such as reed canary grass remove more nutrients than row crops like corn silage. Silage has a higher market value and lower renovative capacity. Information on the interrelationships between crop yields, application rates, effluent composition, weather, and soil types is needed in order to make comparisons between crops, application rates, and renovative abilities.

Issue: Marketing

In many instances a marketable by-product results from wastewater management. The by-products include irrigation water and nutrients, dried sludge, composted sludge, agricultural crops, reclaimed land, and sod production. Research is needed to determine how to manage wastewater treatment systems to maximize economic gains from by-products while maintaining adequate renovation.

The waste constituents can be sold as they come from the pretreatment stage. To develop markets for sludge and/or effluent, factors which influence acceptance by the agricultural community and cost sharing arrangements must be identified. Effluent and sludge are combined products of water, humus, and nutrients. A farmer must be willing to accept all or none of the parts. If he has a clay soil, he may not want the water; therefore, the value of sludge or effluent is lower to him than if he had a sandy soil which needs water.

As the value of water increases, sewage effluents may be recycled in new ways, especially in arid regions. For example, Colorado Springs, Colorado has a dual water system, one for potable sources and the other for irrigating lawns and fire fighting (Sullivan). Infiltration-percolation sites and overland flow sites can realize economic benefits from selling reclaimed water. Phoenix, Arizona plans to sell water pumped from its infiltration-percolation system to irrigation districts.

Reclamation of strip mined lands and recharge of groundwater increase the value of wastewaters, especially in humid areas.

Initial attempts to market effluent or sludge should proceed gradually. A municipality could start with one farm as a demonstration project and gradually expand through a system of bids. Potential users can be encouraged to locate in a given area through the provision of free services such as development aid. The marketing system can be established using either in-house or marketing consultants and long term agreements. Payments may have to be varied to take into account the loss of flexibility in farm operation. It may be best to contract with farmers for the use of their land. Or the wastewater authority can purchase the land and lease it to farmers, as the Metropolitan Sanitary District of Chicago does with a large portion of its Fulton County lands.

Current market price is only one criteria for crop selection. The elasticities of supply and demand in potential product and factor markets also need analysis. Such analysis may show that the best procedure is to develop a market for a low valued crop with a high renovative ability, such as reed canary grass. In some locations it may be possible to develop markets for wastewater such as sod farms, landscape nurseries, fish farms, bait production, and greenhouses. While none of these use significant quantities of water by themselves, they do in combination. The availability of low cost (or free) water, nutrients, and organic material may be a sufficient inducement for these industries to develop or to shift locations.

Impacts of Land Treatment Systems

The operation of a land application site can have a significant impact on the local and regional economies. Three of the four workshops on research needs assigned very high priority to measuring these impacts. (Table 1). Other important impacts involve public acceptance and understanding, equity in pollution control, and the value of the zero discharge goal.

Issue: Impact on Local and Regional Economies

Land of sufficient type and area is required to handle the wastewater design load. It also requires capital and labor that might be put to alternative uses. The composition of the local economy can be altered through restrictions or surcharges on sewer discharges (e.g. metals). Industry can be attracted to a community by the availability of a well operated treatment facility. The construction of a wastewater treatment facility (land treatment included) will increase regional income through a local multiplier, especially when local labor and construction firms are used. Larger projects will exert a continuing influence on employment, tax base, property value, service needs, and the area's crop production. Land treatment of wastewater is expensive. It is estimated that the net annual costs of a land application system for a community of 10,000 are $262,000 as opposed to $345,000 for tertiary treatment (Council of Environmental Quality).[3/] A study is needed to evaluate changes in sales and local income as the local economic structure changes.[4/]

A land treatment system can influence the local channels for production supplies and product marketing. If agriculture becomes more intense, inputs of seed, petroleum products, machinery, and fertilizer may increase.

However, depending upon the substitution of nutrients in the wastewater for commercial fertilizers, these sales could decline.

Marketing could change considerably depending upon changes in cropping patterns and yields associated with land treatment. Additional research is needed to develop a system for estimating these impacts in particular situations. In the area of nutrient substitution there is a need to identify the key parameters determining the potential nutrient savings from wastewater and sludge application to crops.

Issue: Public Acceptance and Understanding of Land Treatment Systems

While land treatment systems are being successfully operated throughout the country, public opinion can prevent the development of additional sites and has done so. With the increased probability of more systems being developed, there is a need for improved understanding of attitudes toward land treatment of wastes. Questions are raised about the health effects of land treatment. An economic approach to this issue is needed to relate the costs of alternative levels of treatment to the probabilities of disease incidence. The concept of marginal costs needs greater application as an alternative to the absolute cost approach commonly advocated by physical scientists.

Problems of siting land application facilities may be similar to those encountered in siting sanitary landfills. Planners will discover that personal involvement will create an intense commitment against a project especially when people feel that they are fighting to protect their homes, their jobs, and aesthetic or recreational areas. A land treatment site can be incorporated into a land use plan to preserve open space near communities. The facility can be operated as parks, golf courses, hiking trails, or as agricultural fields with no public access. On the negative side, a poorly managed system will create increased vector populations, rodent populations, and odors.

When the land application site is located outside the political jurisdiction of the supplying region, additional psychological concerns develop over being the recipients of someone elses wastes. Public attitudes differ concerning accepting land application of wastes from a distant city than application to solve a local problem. The cost analysis of the transport of effluent or sludge from a city such as Washington, D.C. to the countryside may have to include extra safety, precautionary, and public relations factors. The city might want to design the system so that communities located in the application area can hook into the land treatment facility as an extra incentive for the recipient of the wastes. It is essential that some sort of compensation to the receipients be included in the planning. In arid regions the value of the water may be sufficient compensation. In other areas reclamation of strip mined lands and groundwater recharge may increase the value of the effluent.

Issue: Equity in Pollution Control

The beneficiaries of pollution control in streams often do not bear the costs of waste management. The choice of a land treatment system to attain a public policy goal may force a few to pay a disproportionate share of the cost. For example, if a farmer is forced to sell his land for the development of a land system, he is paying a greater share of the costs than is the individual in the served area who may have to pay only a slight increase in taxes for the treatment system. In many instances small rural communities will be required to achieve high level wastewater treatment since they are located on critical watersheds. Research is needed to identify the impact on community financial structure and development needs and to identify inequities in public policy choices.

Issue: Value of Zero Discharge Goal

Much of the work of identifying the most efficient method to meet clean water standards can be thought of as a sub-optimization effort. Additional research is needed to specify a range of water quality levels in a particular stream, with explicit identification of the costs to attain each level. Improved cost-benefit analysis is needed to better specify the value of a clean stream and to determine how the value of nutrient and BOD removal varies with the location of the stream.

Summary

The solution of wastewater management problems requires a multi-disciplinary approach utilizing the skills and knowledge of social, biological, and physical scientists. If land treatment is a feasible solution to the problem, the economic and social implications of this treatment technology need to be evaluated. This discussion has focused on some of the economic issues and research needs relating to land treatment of municipal wastewater.

The issues have been categorized as those relating to system design considerations and the impacts of land treatment systems. Three basic techniques for land application of wastewater are irrigation, overland flow, and rapid infilatration. The economic advantage of any alternative should be evaluated in conjunction with other treatment techniques including conventional as well as land intensive technologies. The empirical evidence indicates that land application may be more advantageous for smaller communities. Several options exist for land acquisition and system management. When evaluating land costs only the extra costs imposed by using the land for wastewater renovation should be considered. Wastewater treatment costs can be financed by bonds, taxes, state and federal grants, sale of effluents and sludges, crop sales, and pricing of sewer services. In choosing a crop for wastewater treatment, the tradeoffs between renovative capacity and market value must be evaluated. A treatment authority may discover that in order to minimize net costs it may be best to develop a local market for a product with a high renovative capacity. The structure of the local economy can be altered through pricing of sewer services, availability of treatment facilities, and local service industries. Land application systems can be incorporated into local land use plans to preserve open space near metropolitan communities. Additional problems will occur when inter-regional transfers of wastes are planned. Psychological fears over health concerns and being the recipient of someone elses wastes can be major roadblocks to land treatment systems. Improved frameworks are needed to measure the benefits and costs of reduced water pollution and to identify who benefits and who pays the costs.

Footnotes

1/ Assuming that the spray field is one half mile away from the treatment plant, a 10 mgd spray irrigation facility will use 9,824 KWH per day. If an equivalent level of treatment is achieved using coagulation-filtration, energy consumption will be 13,829 KWH and 265,000,000 BTU per day (Council of Environmental Quality).

2/ It is not necessary for each facility to purchase harvesting equipment. It can be leased on an as needed basis or a farmer can be hired to harvest the crop.

3/ These values are for wastewater treatment only. Collection costs are not included.

4/ Changes can occur in revenue for trucking firms and agribusiness firms, in local land values, and as new industries such as sod farming and greenhouses develop.

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