Waste

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UPGRADING MUNICIPAL WASTEWATER TREATMENT IN RURAL AREAS*

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The 1972 amendments to the Federal Water Pollution Control Act (P.L. 92-500) call for upgrading municipal wastewater treatment throughout the United States. The amendments established the goal of best practical waste treatment by 1977 and best available treatment by 1983 for all municipal wastewater treatment works. Although some delays have been granted, it is clear that many communities will eventually have to improve their treatment facilities.

Three features of P.L. 92-500 are of importance to rural communities. (1) The Federal government provides a grant to pay for 75 percent of the costs of constructing sewage treatment facilities.1/ (2) P.L. 92-500 call for recycling wastewaters through land application and industrial reuse whenever practical. This requirement has the potential for significant impact on land use in rural America. (3) The Act calls for regional water quality planning. This portion of the Act calls for incorporating the impact of sewage discharges, non-point waste discharges such as agricultural runoff, and industrial discharges into a regional plan.

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1/ Grant funds are not applicable to all construction costs. Land which is not an integral part of the treatment process is not eligible for the subsidy.

The first two features are discussed in this paper and the third in the two following papers in this symposium. Upgrading and expanding municipal wastewater treatment in rural areas imposes a greater per capita financial burden on smaller communities than on larger ones. The subsidies provided by P.L. 92-500 do not offset the financial burden. Encouraging land application of wastewater and its residuals by definition implies that it will have an impact on rural areas, since rural land areas will be required on which to spread effluents and sludges.

Wastewater Treatment Alternatives

Wastewater treatment consists of three separate stages. Primary treatment removes the solids from the wastewater. Secondary treatment is a biological treatment process for decomposition of the organic material contained in the sewage. Secondary treatment significantly reduces the number of pathogenic organisms in the wastewater. Tertiary treatment or advanced wastewater treatment is primarily used for nutrient removal. Most wastewater treatment facilities in the United States provide either primary or secondary treatment. There are few existing tertiary treatment facilities, although P.L. 92-500 calls for their installation by 1983.

Two products result from the waste treatment process. The first is the liquid or effluent which is generally discharged into a stream. The second is the solids or sludge. Sludge is generally disposed of by incineration, by putting it in a landfill, or by spreading onto the land. Ocean dumping has been used by major coastal cities but is being phased out.

In contrast to the centralized collection and treatment options described, rural communities have another option available for wastewater treatment -- the use of on-lot waste treatment systems. The most common on-lot treatment system is a septic tank. These systems are less costly than centralized collection and treatment systems, but do not provide as high a level of treatment as secondary treatment facilities.[2/]

Treatment Costs

Centralized wastewater treatment is relatively expensive. The EPA (1977) estimates that an additional $96 billion will be required to upgrade municipal wastewater treatment to meet the 1983 goals of P.L. 92-500. Representative cost estimates for various wastewater treatment alternatives are presented in Table 1. The selection between treatment processes is based on average costs, the degree of treatment desired or required, and other factors such as system reliability, labor requirements, and input costs.[3/] For example, aerated lagoons appear to be relatively inexpensive based on the cost data presented; but larger communities may not be able to find enough isolated land to construct the lagoons at a reasonable cost. Additionally, aerated lagoons may not be capable of providing a consistently high level of wastewater treatment in some regions of the United States.

There are significant economies of size to wastewater treatment (Table 1). Increasing facility size from a 0.5 million gallon a day (mgd) facility (5000 people) to a 1 mgd facility (10,000 people) results in an average cost reduction of approximately 30 to 50 percent.[4/] Based on the magnitude of economies of size, illustrated in Table 1, it is obvious that

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[2/] When small quantities of wastes are generated, septic tanks can provide an environmentally acceptable method of sewage disposal at a lower cost than centralized treatment.

[3/] Table 1 is not meant to list all treatment alternatives. It is to be used to illustrate relative differences in costs rather than absolute differences. Care should be exercised in comparing the treatment techniques listed in Table.1. Different processes result in different effluent qualities.

[4/] One mgd of wastewater is equivalent to the waste discharges of a community of 10,000 people, assuming no industrial wastes.

TABLE 1

AVERAGE WASTEWATER TREATMENT COSTS FOR VARIOUS FACILITY SIZES (1975 DOLLARS)[a/]

Treatment technique	Type of cost	Facility size (millions of gallons per day) 0.5	1.0	5.0	10.0
		Dollars per 1,000 gallons			
Trickling filter	O&M[b/]	0.27	0.19	0.11	0.07
	Capital[c/]	0.39	0.29	0.14	0.08
	Total	0.66	0.48	0.25	0.16
Activated sludge	O&M	0.34	0.26	0.12	0.10
	Capital	0.36	0.26	0.14	0.09
	Total	0.70	0.52	0.26	0.19
Aerated lagoon	O&M	0.13	0.07	0.03	0.02
	Capital	0.09	0.06	0.03	0.02
	Total	0.22	0.13	0.06	0.04
Activated sludge followed by:					
Nitrification-denitrification	O&M	0.61	0.46	0.23	0.18
	Capital	0.62	0.45	0.24	0.18
	Total	1.23	0.91	0.47	0.36
Lime addition, filtration, sludge recalcination	O&M	0.70	0.56	0.30	0.24
	Capital	0.95	0.73	0.41	0.27
	Total	1.65	1.29	0.71	0.51
Aerated lagoon followed by:					
Solid-set irrigation	O&M	0.23	0.18	0.12	0.11
	Capital	0.72	0.56	0.40	0.38
	NCR[d/]	(0.09)	(0.09)	(0.09)	(0.09)
	Total	0.86	0.65	0.43	0.40
Center pivot irrigation	O&M	0.25	0.19	0.13	0.11
	Capital	0.64	0.48	0.32	0.30
	NCR	(0.09)	(0.09)	(0.09)	(0.09)
	Total	0.80	0.58	0.36	0.32

[a/] The cost estimates are based on information provided by Van Note *et al.* [1975], and Young (1976).

[b/] Operation and maintenance costs.

[c/] Assumes that the discount rate is 5-5/8 percent and the discount period is 20 years.

[d/] Net crop revenue from corn.

requiring uniform levels of waste treatment throughout the United States (e.g., secondary treatment) imposes a financial burden on rural communities relative to larger urban communities without a cost sharing arrangement.

In addition to the economies of size argument, upgrading municipal wastewater treatment in rural areas will have an additional financial impact on communities not having centralized treatment facilities. They must build expensive sanitary sewer systems in order to have centralized treatment. Thus, rural communities that do not have existing centralized treatment facilities are doublely penalized: (1) due to the economies of size in treatment processes and (2) because they do not have a collection system in place.

Construction Subsidies

Communities can receive Federal grants for 75 percent of construction costs to offset the financial impact of constructing wastewater treatment facilities. Net costs to a community receiving a 75 percent subsidy for its capital costs are illustrated in Table 2. With a 75 percent grant a community with a 0.5 mgd activated sludge treatment unit will have its total costs reduced to $0.43/1000 gallons, a reduction of $0.27/1000 gallon. A community with a 5 mgd activated sludge facility will have its costs reduced to $0.16/1000 gallons, a reduction of $0.10/1000 gallons. The subsidy reduces average treatment costs by a larger amount for the smaller facility. This result holds for the other treatment processes illustrated in Table 2.

It is interesting to note that the percent of total costs paid by the local community does not vary as facility size increases. For example, communities with 0.5 or 5 mgd activated sludge plants both pay approximately 60 percent of total costs when they receive 75 percent capital subsidies.

TABLE 2

AVERAGE NET LOCAL WASTEWATER TREATMENT COSTS FOR VARIOUS FACILITY SIZES WITH A CAPITAL SUBSIDY (1975 dollars)[a/]

Treatment technique	Capital Subsidy Level (Percent)	Facility size (millions of gallons per day) 0.5	1.0	5.0	10.0
		Dollars per 1,000 gallons			
Trickling filter	0	0.66	0.48	0.25	0.16
	75	0.37	0.26	0.14	0.09
Activated sludge	0	0.70	0.52	0.26	0.19
	75	0.43	0.33	0.16	0.12
Aerated lagoon	0	0.22	0.13	0.06	0.04
	75	0.15	0.09	0.04	0.03
Activated sludge followed by:					
Nitrification-denitrification	0	1.23	0.91	0.47	0.36
	75	0.77	0.57	0.29	0.23
Lime addition, filtration, sludge recalcination	0	1.65	1.29	0.71	0.51
	75	0.94	0.74	0.40	0.31
Aerated lagoon followed by:					
Solid-set irrigation	0	0.86	0.65	0.43	0.40
	75	0.32	0.23	0.13	0.12
Center pivot irrigation	0	0.80	0.58	0.36	0.32
	75	0.32	0.22	0.12	0.10

[a/] The cost estimates are developed from data presented in Table 1 and assumes that all capital costs are eligible for a subsidy.

Thus, while smaller communities receive larger absolute monetary reductions in average treatment costs they do not receive larger percentage reductions in total treatment costs due to the capital subsidy.

To determine whether or not the capital subsidy actually provides greater average reductions to smaller communities, one would need to compare total expenditures on wastewater treatment to subsidized expenditures for a range of community sizes. To conclude that the subsidy reduces the impact of the regulations on smaller communities, subsidized expenditures would have to cover a greater proportion of treatment costs for smaller communities than for larger communities. Construction grants for wastewater treatment facilities awarded under P.L. 92-500 are presented by community size categories in Table 3. Comparable data on total expenditures are unavailable as the EPA only records grant expenditures and does not maintain records on total expenditures for wastewater treatment.

Some indication of the impact of the current subsidy program can be derived from a comparison of the population distribution of communities and construction grant awards (Table 3). Small communities (less than 5,000 people) have received less from the construction grants program than larger communities (greater than 25,000 people). Considering economies of size and the lack of collection systems in many rural communities, one might expect smaller communities to have received more grant dollars per capita than larger ones. Instead the per capita distribution is relatively constant across community sizes with larger communities receiving slightly more per capita (Table 3). Communities with a population less than 5,000, 12 percent of the urban population, received 9 percent of the dollars awarded for construction grants, while communities with populations in excess of 25,000, which contain 67 percent of the urban population, received 72 percent of the grant monies (Table 3). Small communities have also received fewer grants per community than larger ones. Communities with a population less than

Table 3

DISTRIBUTION OF CONSTRUCTION GRANTS FOR WASTEWATER TREATMENT WORKS AWARDED UNDER P.L. 92-500 COMPARED TO THE DISTRIBUTION OF URBAN POPULATION

Community Size	Urban population[a]		Dollars awards[b]		Awards[b]		Communities[a]	
	Number (millions)	Percent	Amount (millions)	Percent	Number	Percent	Number	Percent
Less than 2500	9.7	7	458	6	2,263	43	13,237	72
2501-5000	6.7	5	254	3	749	14	1,911	10
5001-10000	9.8	8	480	6	621	12	1,397	7
10001-25000	17.6	13	1,014	13	649	12	1,134	6
25001-50000	15.7	12	898	11	319	6	453	3
More than 50,000	72.6	55	4,897	61	697	13	384	2
Total	132.2	100	8,044	100	5,303	100	18,516	100

[a] Source: U.S. Department of Commerce (1974).

[b] Source: U.S. Environmental Protection Agency (1976).

5,000, the population category of 82 percent of the communities, received 57 percent of the grants, while communities with more than 25,000 population, 5 percent of all communities, received 19 percent of the grant awards (Table 3). Smaller communities have received fewer grant dollars than their number and populations would lead one to expect.

The construction grants program does not offset the higher per unit treatment costs which smaller communities must pay to comply with wastewater treatment requirements. For the grants program to reduce the impact of economies of size demonstrated in Table 1, small communities would have to receive more per capita of the grant monies than larger communities. The data in Table 3 demonstrates that small communities receive less than larger communities, indicating that the current subsidy programs do not reduce the negative effects suffered by the smaller communities due to P.L. 92-500.

Two suggested approaches for reducing the cost burden of sewage treatment regulations for small communities due to economies of size and cost sharing differences are: requiring less wastewater treatment in rural areas when possible and relating the federal share of total costs to community size.

The cost of wastewater treatment for small communities can be reduced by tailoring the required level of treatment to local water quality conditions. In many regions of the United States, small discharges of partially treated wastes will not have a significant affect on the environment. The volume of water in receiving streams is relatively large compared to the population density so the streams can assimilate the wastes.

An alternative solution is a transfer of additional resources to rural communities using subsidies. If society imposes demands for advanced levels of treatment on rural communities, it may elect to share a larger proportion of treatment costs. The failure of existing cost-sharing formulas to reduce the impact on rural communities is discussed in the previous section. The subsidy could decrease as community size increases. The subsidy could cover up to 100 percent of construction costs and some proportion of operation and maintenance costs. An expensive treatment facility is useless if the local community cannot afford to operate it. For example, operation and maintenance costs for a 0.5 mgd activated sludge treatment facility are $0.34/1000 gallons, while for a similar 5 mgd facility total costs are $0.26/1000 gallons (Table 1). Thus, even with a 100 percent capital subsidy, treatment operation costs for the 0.5 mgd facility are higher than the unsubsidized costs for the 5 mgd facility. If the 5 mgd facility receives a 75 percent capital subsidy, local costs are $0.16/1000 gaoons (Table 2). For the smaller facility to have similar local treatment costs, a 100 percent capital subsidy and a 50 percent subsidy for operation and maintenance costs is required.

<u>Land Application of Effluents and Sludges</u>

The second major impact of P.L. 92-500 on rural America is the increased emphasis being given the concept of recycling wastewater and sludges onto land, particularly agricultural land. Land application of wastewaters and sludges will impact rural communities in two ways. First, in many cases it is the most cost-effective method for high level wastewater treatment and for sludge disposal for small communities (Table 1). Second, when larger communities decide to use land application they will have to go to rural areas in order to obtain sufficient land areas. For example, the city of Chicago transports its sewage sludge 200 miles south to Fulton County, Illinois in order to dispose of it onto land (Zenz, Peterson, Brooman, and Leu-Hing, 1976). Muskegon, Michigan pumps 27 mgd of wastewater 11 miles to its land application site (Walker, 1976).[6/] Land application by large communities in rural areas may or may not benefit rural regions. A well run land application system can increase job opportunities, agricultural production, and open space. A poorly operated system may have odor problems, may be a health hazard, and may be aesthetically displeasing to view. A publicly owned land treatment system will remove land from the tax rolls, which can have a significant effect on property tax revenues.[7/]

Land application refers to the controlled discharge of partially treated wastewater or sewage sludge (solids) onto the land. The soil filters and biologically reduces the components in the sewage. Sewage effluent can be applied to land using solid-set irrigation systems, center pivot irrigation systems, flood irrigation techniques and infiltrations basins.[8/] Sewage sludge can be applied to the land by several means. As sewage sludge comes from the wastewater treatment process it contains approximately 95 percent water and can be considered a liquid. In this form, it can be sprayed onto the land using irrigation equipment; it can be sprayed onto land using a tank truck; or it can be injected into the soil using special application equipment. By injecting sludge into the soil odors and nitrogen losses due to volitization are reduced. Sludge can be dried to approximately 80 percent moisture content resulting in

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[6/] The design flow at Muskegon is 42 mgd.

[7/] Chicago makes a payment to Fulton County in lieu of taxes.

[8/] An infiltration basin is a shallow pond which through intermitant wetting and drying cycles applies sewage at the rate of 1 to 2 acre-feet per week to the land.

an 80 percent volume reduction and applied to the land as a solid using a conventional manure spreader or special sludge handling equipment. The sludge can be further dried using heat treatment to kill pathogens. Milorganite, heat dried sludge from Milwaukee, Wisconsin, is such a product. Alternatively, the sludge can be composted to provide a very high degree of pathogen kill. Composted sludge can be handled easily with few odor problems.

Land application is one of the least expensive alternatives available to achieve high level wastewater treatment, especially for smaller communities. A 0.5 mgd center pivot irrigation system will cost a community approximately \$0.80/1000 gallons opposed to a \$1.65/1000 gallon for a lime addition, filtration advanced waste treatment system (Table 1). The lime addition, filtration advanced wastewater treatment system and the irrigation systems provide equivalent levels of wastewater treatment. The relative cost advantage of land application of effluent decreases as facility size increases. The 10 mgd center pivot irrigation system costs \$0.32/1000 gallon as opposed to \$0.36/1000 gallon for the lime addition filtration advance wastewater treatment system (Table 1). Based on this cursory cost examination, it seems likely that land application will be most effective for smaller communities. Larger facilities will face an additional disadvantage in the use of land application. As the area required for the land application system increases, land acquisition costs will probably increase in order to obtain a continguous site. A 50 mgd land application system will require more than 10,000 acres in order to apply 2 acre inches of wastewater per week to the land.

Land application of sewage sludge is likely to be used by communities of various sizes. If a community's sewage sludge does not contain toxic metals or chemicals, it is likely that land application is the least expensive alternative for disposal of sewage sludge available. Land application and landfill disposal of sewage sludge cost approximately the same amount per gallon of sludge and are considerably less expensive than incineration (Young, in press). When toxins are present in the sludge, the community can force industrial dischargers to remove them via pretreatment regulations or surcharges as discussed by Carlson and Seagraves (1977).

A major advantage of land application of wastewater and sludges in addition to wastewater treatment is the production of a by-product -- agricultural crops -- which can offset a portion of treatment costs. At an application rate of 2 acre inches per week of sewage effluent in Pennsylvania, agricultural yields generally exceed crop yields using fertilizer (Sopper and Kardos, 1973). Two acre inches of effluent applied for approximately 40 weeks a year supply equivalent quantities of nutrients to recommended fertilizer practices for Pennsylvania. Yields have also been shown to increase with application of sewage sludge over time (Kelling, Walsh, and Peterson, 1976). Four major constituents of effluent and sludge are useful to agricultural crops: water, nitrogen, phosphorus and organic matter.

Land application of effluent has been used throughout the United States for many years, especially in the arid southwestern states. The distribution of land application sites throughout the United States in 1968 is shown in Table 4. Land application predominated in California, Texas, New Mexico and Arizona. In these states the average value of water for crop irrigation is high relative to the rest of the nation. Most of these facilities selected land application since it was less costly than conventional wastewater treatment. Land application systems in arid states

Table 4. Distribution of municipal land treatment sites in the United States by states in 1968[a/]

State	Number of land treatment sites	Number of wastewater treatment plants	Percent using land treatment
California	259	534	48.5
Texas	106	918	11.5
New Mexico	28	82	29.3
Arizona	17	79	21.5
Nevada	12	36	30.0
Oklahoma	3	374	0.8
Maryland	11	154	14.0
New Jersey	2	380	0.5
North Carolina	14	384	3.6
West Virginia	3	101	3.0
Florida	5	535	0.9
Alabama	1	267	0.4
Virginia	1	301	0.3
Colorado	2	154	1.3
Wyoming	4	82	4.9
Washington	10	140	7.1
Oregon	6	178	3.4
Nebraska	1	434	0.2
Massachusetts	1	192	0.5
Kansas	1	477	0.2
Wisconsin	4	499	0.8
New Hampshire	2	79	2.5
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[a/] Young and Carlson, 1974.

will be expected to use lower application rates and therefore more land in order to maximize net crop revenue from the system. Systems in more humid regions will be expected to base their application rates on nutrient concentrations.

Summary and Conclusions

Upgrading the level of wastewater treatment as mandated by P.L. 92-500 will have a serious impact on rural economies. Centralized wastewater treatment is very expensive. This is particularly significant for small communities where per capita costs are higher due to economies of size in wastewater treatment. Average wastewater treatment costs fall in excess of 50 percent as facility size increases from 0.5 mgd (5000 people) to 5 mgd (50,000 people). Rural communities not having collection systems in place will incur additional cost for their construction. Public Law 92-500 provides subsidies to offset a portion of the wastewater treatment costs. If all communities obtain the federal grants, smaller communities save more per unit of wastewater treatment than do larger communities but per unit costs remain higher for the smaller communities. Examination of EPA construction grant awards indicates that small communities have received fewer grant awards than larger communities and that smaller communities have not received more grant dollars per capita than larger communities.

A second major impact of P.L. 92-500 on rural communities is the increased emphasis on land application of wastewater as a method for advanced wastewater treatment and for sludge disposal. For smaller communities land application of sewage effluents is an economical method for advanced wastewater treatment. This is especially true in those areas where crop yields increase substantially due to the water and nutrients contained in the sewage effluent. Land application of sewage sludge is likely to be utilized by many communities throughout the United States. It is one of the least costly methods available for disposal of sewage sludges which do not contain toxic contaminants.

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