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FOR LAND APPLICATION OF SLUDGES

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I. Introduction

Two often conflicting points of view must be considered in the selection of a sludge disposal method. On one hand, society desires a non-polluting, odorless, safe, and cheap disposal methods that conserves natural resources. The sludge manager, however, faced with the monumental task of disposing of sludge on a daily basis, desires a high degree of control over the disposal system with high reliability and minimum cost.¹ Many other factors may also affect the decision-making process of the manager. Some of these are political constraints, social concerns, land availability, land-use effects, public-health impacts, marketability of the treated sludge, ease of implementing the disposal method, and flexibility in handling input and output materials. Because of the complex nature of the decision, generally a number of plans are developed and then compared point-by-point. One fact quickly becomes apparent, there is no single or simple solution to the sludge disposal problem.

This paper will 1) point out the general pressures that are forcing sludge managers to reconsider land application of sludges where it is not already used; 2) present the cost of using gamma-radiation from the isotope cesium-137 for sludge disinfection; and 3) document the economic and social pressures that could compel a city such as Washington, D. C. to disinfect its compost before sale.

Washington was chosen as an example because it is a city for which suitable compost marketing data are readily available. With these data it is reasonably straightforward to document the costs and benefits of radiation processing. The economic and social pressures that affect Washington are probably similar to those in many other areas where the radiation disinfection of dried sludge could provide the same disposal options.

II. Present Disposal Practices

Our national sludge production is currently disposed of as shown in Table 1.

Table 1. Sludge Disposal Practices²

<u>Disposal Method</u>	<u>Percentage Use</u>
Ocean Dumping	15%
Incineration	35%
Landfill	25%
Land Application	
Crops	20%
Other	<u>5%</u>
Total	100%

One-fourth of our annual sludge production is used in a beneficial way through land application.

All of the currently practiced disposal methods are under pressure because of environmental concerns for air, water, and land. Our Federal, State, and local governments have translated these environmental concerns into laws and regulations which control, limit, or prohibit each disposal method.³

A 1977 Federal law⁴ prohibits ocean dumping of sewage sludge after 1981. Cities such as New York, Boston, and the City of Los Angeles, which currently dispose of their sludge in the ocean, will be required to convert to one or more of the other three disposal methods cited in Table 1.

Incinerators are useful, but have limitations. Fuel prices have risen rapidly in recent years, and fuel availability is uncertain over decade intervals. Cities which desire to install new sludge incinerators may be within air-quality maintenance districts where other air pollution sources must be eliminated before new ones are allowed. A number of Federal, State, and local regulations exist for the operation of incinerators. The most important Federal regulations define standards of performance⁵ and set hazardous pollutant levels.⁶ Additionally, incineration is a volume reduction, not a sludge disposal, method since it leaves an ash (approximately 30 percent by dry weight) which must be disposed of in a landfill. The use of landfills is subject to additional Federal regulations noted below.

Federal regulation of solid waste disposal by landfilling is detailed in EPA guidelines;⁷ and procedures for the maintenance of groundwater quality near landfills are mandated in other regulations.⁸ Unavailability or unacceptability of nearby land for landfills, high transportation costs to sites suitably distant from cities, and nuisance complaints make landfill disposal less attractive as suburban areas expand outward from core areas.

Considering the chronic, or in some cases terminal, nature of the problems that face ocean disposal, incineration, and landfill of sewage sludge, the option of conversion of sludge to a safe and useful soil-conditioner with some fertilizer value is given serious consideration in this paper. Current concerns about land application of sewage sludges are centered on their heavy metals content which could get introduced into the food chain and on the potential health hazard due to pathogen content.³ Unless the sludge is suitably stabilized before land application, odors and other nuisance conditions can also cause problems.

If the sludge is dried after stabilization, it is more acceptable to consumers because it is easier to transport and spread than liquid sludge and it more closely resembles traditional fertilizer materials. The heavy metals problem can probably be reduced by source control in most cities. According to the CAST report,⁹ controlled application of troublesome sludges to restricted-use land would usually solve their disposal problems.

Another aspect of the land application option that often appears promising is to process the sludge to the point that it can be safely used by large markets near the source of the sludge. The economics of the secondary aspect will be examined more thoroughly later for Washington, D. C. The assumption is made that the heavy metals problem has been dealt with by implementation and enforcement of source control procedures.

III. Land Application for Disposal of Sludge

Sewage sludge generally requires treatment of some kind before it can be applied to the land. The treatment normally stabilizes the sludge to some degree. If the sludge is then dried, it is less expensive to transport and usually easier to apply to the land.

The land application of digested liquid sludges is restricted because high transportation costs are incurred in getting the sludge to areas sufficiently remote that the sludge does not create unreasonable odors or other nuisances. Where transportation costs are low and suitable land is available, this disposal method may be appropriate. Because cost of barge transportation down the Illinois River is relatively inexpensive, Chicago is currently barging part of its digested sludge to Fulton County in Illinois where the sludge is used to reclaim strip-mined land.

The most generally used treatments that produce a sludge product suitable for land applications are described below.

Due to the problems with disposing of liquid sludge, many cities air-dry their anaerobically digested sludge on sand drying beds and use, distribute, or sell the resulting product.¹⁰ This product can be disposed of either ground or unground, in bags or in bulk. The product typically has poor quality control and receives no additional disinfection beyond the air-drying process. The final product has probably not seen a treatment severe enough to kill the ova of Ascaris lumbricoides, which are among the most abundant parasitic species in sludges.¹¹

The cities of Milwaukee, Chicago, and Houston currently heat-dry waste activated sludge, which they wholesale either in bulk or in bags. Typical prices are about \$25/dry ton for the bulk product and about \$70/dry ton bagged. The sludge is subjected to a very high temperature in the drying process and is consequently sterilized. The disadvantage of this type of process is that costs range from \$135 to \$165/dry ton exclusive of the capital cost for the drying facilities. The process is also very energy intensive.

Because of the problems with disposal of municipal liquid sludges and the high cost of heat-drying them, interest in the composting process has been revived.¹² Composting sludges produces a relatively odor-free soil conditioner with some fertilizer value. Cost data for this process have been generated¹³ and a market survey for the resulting product was made for the Washington, D. C. metropolitan area.¹⁴ This method of making a product suitable for land application is feasible and appears to be cost-effective. Until recently, however, public-health concerns restricted the use of the compost from its

largest potential market, the private residence owner.¹⁵ A recent decision has allowed the compost into the private residence market if regular pathogen assays and heavy-metals analyses indicate "continued suitability of the raw product".¹⁶ The nature of the problem of maintaining a pathogen-free product is such that an inexpensive disinfection technique is needed which could produce a quality-controlled product with respect to pathogen destruction. If the compost is disinfected after bagging, the bacterial pathogen regrowth problem¹⁷ might be eliminated. Because there is also a clearly identifiable market for compost that has not been disinfected, the questions of the economics, enhanced market potential, and effect on product value of a disinfection process remain. Although the costs presented here have some small uncertainties because of site dependent effects, the major factors that affect whether or not disinfection will be cost-effective have been identified and can be further quantified in specific geographical locations with more complete market studies.

IV. Radiation-Processing Costs

The basic questions relating to the desirability of disinfection of air-dried or composted sludges have been noted. Cost data for a disinfection process using radiation from a cesium-137 source have been developed and are presented below.

Sandia Laboratories, through an Interagency Agreement between the Department of Energy (DOE) and the Environmental Protection Agency, (EPA), has been doing research for several years on the radiation disinfection of both liquid and dried sewage sludges. Last year at the Third National Conference on Sludge Management Disposal and Utilization, tentative radiation-processing costs were given for dried sewage sludges.¹⁸ Since these data were presented, joint studies

with Battelle Pacific Northwest Laboratories have resulted in more accurate capital and operation and maintenance cost estimates for Sandia-designed liquid and dried sludge irradiators.^{1,19}

Dry sludge radiation-processing costs are based on design experience with a pilot plant currently under construction at Sandia Laboratories in Albuquerque, New Mexico. The pilot facility is designed to treat 8 tons/day of sludge to a 1 megarad dose. The costs presented here are based on a gamma-source of cesium-137 large enough to treat the compost to this dose.

The capital costs shown include site preparation, concrete work, grouting, stainless-steel tank materials, steel reflector plates, access ladders, pumps, ventilators, filters, a lead shield door, source plaques and drives, a fire-suppression system, a radiation alarm system, mechanical and electronic interlock systems, conveyor, hopper, miscellaneous mechanical work, and installation. Labor requirements include loading the feed hopper, maintaining the conveyor assembly, and periodically checking the air filters. Electrical power requirements include the conveyor drive, air blower, and alarm system. Materials and supply costs include replacement of air filters and maintenance of the conveyor assembly. The gamma-source material cost was calculated under a rather complex set of assumptions outlined in another paper.¹⁸ A purchase price of \$.10/curie is assumed. Radiation-processing costs for compost (50 percent solids content) are given in Table 2.

Table 2. Component Costs for Radiation-
Processing of Compost

<u>Component Cost</u>	<u>Quantity Irradiated (tons of compost/day- 50% solids)</u>			
	<u>10</u>	<u>25</u>	<u>50</u>	<u>100</u>
Capital (0% interest)	7.41	4.68	2.90	2.16
(7% interest)	14.00	8.85	5.48	4.08
Labor	2.68	1.80	1.50	1.35
Electric Power	.24	.14	.10	.05
Maintenance Materials	.10	.05	.03	.02
Cesium-137 Cost (0% interest)	1.55	1.30	1.22	1.22
(7% interest)	<u>3.94</u>	<u>3.64</u>	<u>3.57</u>	<u>3.57</u>
Total Cost per Ton of Compost				
(0% interest)	11.98	7.97	5.75	4.80
(7% interest)	20.96	14.48	10.68	9.07

The total costs are presented in graphical form in Figure 1 for both 0 percent and 7 percent interest rates with a 20 year amortization scheme. The component costs are presented in Figure 2. Keep in mind that these costs are normalized per ton of compost, which has approximately a 50 percent moisture content. To obtain the cost per dry ton, the costs must be doubled. This per-ton-of-compost normalization scheme seemed the most natural because all the market data is presented in this format.

These cost data were used to develop the Washington, D. C. site specific case study in the next chapter.

Figure 1. Cost to Radiation-Process Compost

Figure 2. Component Costs of Radiation-Processing

V. Potential Benefits of Disinfection of Compost for the Washington, D. C. Metropolitan Area

The sludge disposal options open to the Washington, D. C. metropolitan area and the costs and limitations of these options have been well documented.^{12,20,21,22} From a number of points of view, composting, as developed by the U. S. Department of Agriculture at the Agricultural Research Station in Beltsville, Maryland, is a satisfactory solution to this sludge disposal problem. It is presumed that the process can be scaled up at the projected costs without odor or public-health problems. The projected costs for composting are a small fraction of the current costs of land disposal.²²

In order to determine where the market for composted sludge in the Washington, D. C. area was and to quantify it, a market study was prepared by the Urban Services Group, Inc., for the Metropolitan Washington Council of Governments.¹⁴ This study segments and quantifies the user markets in different areas around Washington. A summary of data from this report will be used in the following arguments. For the purposes of this report, the results were chosen to represent two areas. Area A, shown in Figure 3, is bounded by a circle with an approximate 35 mile radius. The area labeled B, also shown in Figure 3, is the area bounded by a circle with approximately a 100 mile radius, but does not include area A. The average distance from the center of area A to a point in area A is approximately 23 miles. The average distance from the center of area A to a point in area B is approximately 73 miles. These distances will be used to estimate sludge product transportation costs.

The market data for the two areas are presented in Table 3.

Figure 3. Market Study Areas in the Washington, D.C. Metropolitan Area¹⁰

Table 3. Constrained Market Potential¹⁴

<u>Market Category</u>	<u>Market Size (thousands of tons of compost/year)</u>	
	<u>Area A</u>	<u>Area B</u>
1. Public Agencies (PA) - military installations, municipalities, parks, and others	237.3 - 594.1	1708.1 - 4043.3
2. Quasi-public Agencies and Private Firms (QPA&PF)- horticultural establishments, turf farms, golf courses, institutions, airports, metro facilities, and others	100.1 - 373.4	344.5 - 1241.5
3. Private Residences (PR) - existing and new	0 - 1072.1	0 - 3157.5
Totals	337.4 - 2039.6	2052.6 - 8442.3

If all the sludge from the Washington, D. C. metropolitan area were composted, approximately 275 thousand tons of compost would be produced per year.¹⁴ When construction of planned waste-water treatment facilities is completed, the amount of sludge will increase significantly and may well double.¹⁴

The size of the PA and QPA&PF markets in area A is 337.4 to 967.5 thousand tons per year, or 125.0 to 471.9 thousand tons per year exclusive of military installation requirements. Note that the anticipated compost production of the Washington, D. C. metropolitan area is very close to the lower bound of the PA and QPA&PF markets in area A. In other cities, which presumably have fewer military installation users, the PA and QPA&PF markets in the central area A may not be able to utilize all the compost that is generated. The sale price of compost to the PA and QPA&PF markets, which do not require disinfection, has

been estimated to be \$4 to \$10/ton of compost.¹⁰ These figures have not been proven by actual trial marketing.

Transportation costs have been estimated for Chicago to haul compost to the users.¹⁰ These costs, which include capital, operations and maintenance, and labor, have been converted to cost per ton of compost and are shown in Figure 4. A compost density of 1,100 pounds/cubic yard was used for the conversion. Handling and loading costs for Chicago have been estimated to be approximately \$1 to \$4/ton of compost. Using the average distances given earlier for Washington and using interpolation and extrapolation with these data, average haul costs of approximately \$4/ton of compost for area A and approximately \$15/ton of compost for area B were determined. These costs are based on transporting at least 50,000 tons of compost/year.

Bagging costs have been estimated to be approximately \$16/dry ton for Milwaukee.¹ This cost includes loading of bags for shipping. If greater than 200 tons of compost per day are bagged, bagging costs of less than or equal to \$16/ton of compost can be expected.

With the market characteristics, market sizes, market locations, and transportation costs given, a number of scenarios can be developed for the use of radiation processing for additional compost disinfection. It will be assumed that compost disinfection is required to enter the PR market.

Scenario #1

The PA and QPA&PF markets in area A may be able to utilize all the compost that is generated, but in order to increase the size and security of the market base and perhaps gain additional income, Washington could decide to enter the PR market in area A.

If Washington decides to enter this market, they could either radiation-process the compost and sell it in bulk, or radiation

Figure 4. Compost Transportation Costs for Chicago¹⁰

process the compost and then sell it bagged. An additional price of \$9/ton of compost must be obtained to cover the cost of disinfection and approximately \$16/ton of compost must be obtained to cover the cost of bagging. A production rate of at least 200 tons of compost per day is assumed. Using a market price of \$4 to \$10/ton of compost for bulk, untreated compost, a price of \$13 to \$19/ton of compost must be obtained for bulk disinfected compost and a price of \$29 to \$35/ton of compost must be obtained for bagged, disinfected compost to cover the cost of the additional operations. If a markup of 2 to 1 is assumed for the retailer, the upper bound of the bagged price implies a retail price of \$1.75/50 pound bag. This is the approximate retail price for a comparable bagged Los Angeles compost product.

Scenario #2

Washington could decide, as the County of Los Angeles has done, to sell its compost to a private contractor for blending and bagging. The private contractor, because of public-health regulations or poor consumer acceptance of the products, might not accept the compost unless it is guaranteed pathogen-free. Disinfection might be necessary for this disposal option.

Washington cannot expect the additional cost of compost disinfection to be borne by the contractor, because competing bulk products are priced in the \$4 to \$10 per ton range. The extra \$9/ton of compost must be absorbed by the sludge producer as a disposal cost.

Scenario #3

Washington could choose to sell bulk compost to the PA and QPA&PF markets in area A, but either due to misjudgement of the market, or poor market penetration, these markets could not utilize all of the compost. The question to be addressed in this case is, "Should the

excess compost be further processed to the point that it can be sold to the PR market in area A, or should the PA and QPA&PF markets in area B be utilized, even though the transportation costs are high?"

This scenario is the most likely one to occur in Washington and other cities of similar size. As stated earlier, a differential price of \$9/ton of compost must be obtained for radiation processing, and a differential price of \$25/ton of compost must be obtained to cover the radiation-processing and bagging operations. However, to reach the PA and QPA&PF markets in area B, a \$15/ton of compost transportation charge must be paid rather than a \$4/ton of compost charge for area A. A transportation differential cost of \$11/ton of compost must be paid to reach area B. Prices of \$18 to \$24/ton of compost must be obtained for the bagged product, and \$2 to \$8/ton of compost must be obtained for the disinfected, bulk product to compete with the PA and QPA&PF markets in area B. These wholesale prices for either bagged or bulk compost products are low compared to the prices for similar products.¹⁰

VI. Conclusions

The pressures that are forcing many cities to reconsider land application for disposal of their sludges have been documented. The alternative processes that produce a product suitable for land application have been described. Composting is one relatively inexpensive process that produces a product suitable for land application. The cost to radiation-process the compost in order to further disinfect it for the private residence market has been shown to be approximately \$9/ton of compost if greater than 100 tons of compost per day are treated. Using the Washington, D. C. metropolitan area as an example, a number

of scenarios have been constructed where it may be necessary and/or economically cost-effective to radiation-process the compost.

The major thrust of this paper has been to evaluate the incremental cost/benefit of radiation-processing an already dried or composted municipal sludge. However, the larger question of other sludge disposal options and their costs must also be considered. The current cost of trucking and trenching sludges in the Washington, D. C. area averages about \$250/dry ton.²² If composting at \$30 to \$50/dry ton¹³ and radiation-processing at \$18/dry ton results in a socially acceptable and pathogen-free product given away free, the city of Washington could save \$182 to \$202/dry ton processed. Such reduction of the negative balance in municipal budgeting for sludge disposal appears to be an objective worth pursuing.

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