Biosolids
Disposal in Pennsylvania

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Biosolids Disposal in Pennsylvania

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TABLE OF CONTENTS

Introduction 5
Project Objectives and Methodology 8
Inventory of Biosolids Disposal Practices in Pennsylvania 8
Statewide Survey of Biosolids Management Practices 9
Results 9
Inventory of Biosolids Management in Pennsylvania 9
Specific Management Practices 10
Statewide Distribution of Management Practices 12
Biosolids Management Costs 13
Factors Influencing Management Practices 14
Conclusions 15
Biosolids Management Practices 15
Biosolids Management Costs 16
Factors Determining Current Practices 18
Looking Forward 18
Policy Considerations 19
References 21

EXECUTIVE SUMMARY

Centralized wastewater collection and treatment, while providing numerous health and environmental benefits, produce by-product solids that present a set of complex issues and challenges. Biosolids are wastewater solids treated to meet contaminant standards that make them suitable for recycling. Currently, three major biosolids management options exist in Pennsylvania: land application, landfilling, and incineration.

To assess current biosolids management practices and associated costs for Pennsylvania's municipal wastewater treatment plants (WWTPs), in 2005, the researchers inventoried current biosolids disposal and recycling methods in Pennsylvania; evaluated the financial costs associated with the major disposal methods; and explored relevant public policy implications and recommendations as they relate to the state's rural communities.

The researchers policy considerations were guided by the principles that: biosolids management options must be affordable for small communities and promote the welfare of rural residents; since *no* biosolids management options are environmentally benign in all respects, future policies must strike a balance between environmental protection and affordability; and consistent with Pennsylvania Department of Environmental Protection priorities, emphasis should be placed on beneficial use and recycling rather than disposal.

The researchers proposed three specific policy directions:

- Ensure continued availability of landfilling for biosolids management with the ultimate objective of nutrient reuse and energy recovery.
- Agricultural use should continue to be promoted as a beneficial reuse option.
- Policies should encourage biosolids use in reclamation of degraded lands and brownfield sites.

INTRODUCTION

Managing human waste is a long-standing challenge for society, and a fundamental service of government that is vital to human health and the environment. Centralized collection and treatment, while providing numerous health and environmental benefits, produce by-product solids that present a set of complex issues and challenges. Biosolids are the by-product solids of wastewater treatment that meet microbial and chemical contaminant standards making them suitable for land-based recycling.

Next to Texas, Pennsylvania has more wastewater treatment plants (WWTPs) than any other state. Rural communities statewide benefit from, and are impacted by, wastewater treatment facilities. Of the more than 700 WWTPs in the state (DEP, 2004b), about 500 serve small communities and have flow capacities of less than 1 million gallons per day (million gallons per day). A large proportion of rural residents rely on septic systems, and much of the septage is disposed at wastewater treatment facilities and becomes a contribution to biosolids production. Most land application of biosolids is accomplished in rural areas, either for agricultural production or mine land reclamation. Besides accomplishing ultimate disposal, land application allows recycling of crop nutrients and organic matter, a clear benefit to the farming community. While such benefits have direct financial value, issues such as odor and truck traffic may affect the quality of life in rural communities since land application and landfilling are predominantly carried out in rural areas.

While there are numerous published studies that compare the quality of and contaminant levels in biosolids from various processes, there are relatively few published studies that compare the economics of different biosolids disposal practices. McMillon et al. (2000) suggest this lack of information has a historical basis. For decades, treated biosolids were sent to a landfill, buried, or stored indefinitely in lagoons. With the promulgation of federal (40 CFR Part 503) and state (25 PA. Code Chap 271) regulations that provided guidance for land application, local governments began to investigate the cost implications of alternative biosolids management options. Increasing awareness that solids management costs represent a significant portion of the total budget for wastewater treatment has further stimulated interest.

Regulatory policies play a key role in defining biosolids management. In New Jersey, for example, traditional landfill disposal is allowed only under "emergency" conditions, and no biosolids are currently disposed in landfills (Pilawski, 2004). This policy has encouraged biosolids recycling in New Jersey, but has also resulted in increased export. In 2002, 43 percent of New Jersey's biosolids production were beneficially used or landfilled out of state, with Pennsylvania being one recipient. Maine recycles more than 90 percent of its biosolids via land application as a result of an intentional effort on the part of the state regulatory agency to create a comprehensive and effective regulatory program (NEBRA, 2001). Key to this effort has been progressive regulations that integrate biosolids management into statewide nutrient management policies. Land application in New Hampshire diminished from more than 50 percent of total biosolids production to less than 30 percent due to state and local regulations that discouraged bulk application of Class B biosolids. Because of a regulatory structure that does not encourage land application, Connecticut recycles only about 3 percent of its biosolids while more than 90 percent of the wastewater solids are incinerated (NEBRA, 2001).

Legislators need quantitative information on the economic implications of proposed legislative actions that restrict land where biosolids can be spread or discourage farmers or municipalities from involvement in biosolids recycling programs. Changes in the clean air regulations impact the cost of biosolids incineration. The imposition of the phosphorus (P) index for land application of manures and other organic fertilizers will undoubtedly impact biosolids recycling on land. Regulations which increase the cost of landfill operations will be passed on to those who produce materials (including biosolids) that are routinely landfilled.

Future policy decisions will impact biosolids management practices in Pennsylvania. Regulatory policies and guidelines should be promulgated with full knowledge of the potential costs and outcomes. This research provides usage information and cost comparisons of alternative biosolids management practices in the commonwealth. This information will assist decision-makers in considering various regulatory strategies that impact biosolids management.

The array of operations available for processing wastewater solids is large, and the chosen processes are influenced by many factors, such as utility and labor costs, space requirements, proximity to farmland or landfills, local climatic conditions, odor control needs, and regulatory requirements. While the exact combination of processes can be quite variable, the three most common options for ultimate disposition of wastewater solids in Pennsylvania are land application, landfilling, and incineration. From a broad perspective, land application is a beneficial reuse option, while landfilling and incineration are non-reuse options. However, in practice, this categorization is not so clear-cut. Biosolids can be used at landfills to enhance the ability of final soil cover to promote vegetation. The energy content of biosolids can sometimes be recovered in the incineration process or through biogas recovery at a landfill receiving biosolids. Following is a brief overview of the three options.

Land Application

Land application is the addition of biosolids to soil to introduce nutrients and organic matter. The traditional land application method is the use of biosolids on agricultural land to enhance crop growth. In this case, the application rate is based on satisfying the nutrient (usually nitrogen) requirement of the crop to be grown. Typically, four to eight dry tons of biosolids are applied per acre to satisfy the demand for row or forage crops. Several methods are used to apply the biosolids, depending on the solids content. Liquid biosolids can be injected into the soil, usually by a special vehicle that has injection nozzles that release the biosolids under the soil surface. Liquid biosolids can also be surface-applied with subsequent incorporation using traditional tillage equipment. Surface application of semi-solid or dry biosolids can be accomplished with equipment similar to that used for manure spreading.

The U.S. Environmental Protection Agency's (EPA) 40 Part 503, Standards for the Use and Disposal of Sewage Sludge, called the Part 503 Rule, regulates various biosolids disposal options. The Part 503 Rule divides biosolids into Classes A and B, based on pathogen levels (and hence the degree of treatment). Class A biosolids have very low levels of pathogens and the low potential to attract vectors (flies, rodents) and, if they meet high-quality pollutant concentration limits, can be applied with no more restrictions than other soil amendment products and fertilizers. Such products can also be marketed for distribution to the public. Pathogen reduction for Class A materials is accomplished through methods like composting or heat drying, which use elevated temperatures for pathogen destruction, or through the use of harsh (strongly alkaline or oxidizing) chemicals. Class B biosolids have higher levels of pathogens than Class A materials but are considered safe for bulk application to land when spread in accordance with the Part 503 regulations. Class B products are typically stabilized by digestion (aerobic or anaerobic) or lime addition. Presently, most land-applied biosolids are Class B materials.

A land application activity of particular importance in Pennsylvania is the use of biosolids in reclamation of lands disturbed by the mining of coal, sand, gravel and other minerals. In this state, biosolids application rates of up to 60 dry tons per acre are permitted. Research has shown that biosolids can effectively revegetate mined lands without adverse impact on soils, vegetation or groundwater (Sopper, 1993). Because biosolids provide both quick- and slow-release nutrients, they provide an advantage over commercial fertilizers for establishing and sustaining vegetation. Additionally, the organic matter in biosolids improves moisture-holding capacity of the surface material.

Landfilling

Biosolids can be disposed in a municipal solid waste (MSW) landfill. According to federal regulations (40 CFR Part 258), biosolids disposed in municipal waste landfills should not contain free liquid, which generally means dewatering to a solids content of 20 percent or higher. According to state regulations (Section 273.513) biosolids placed in a municipal landfill in Pennsylvania must also meet Class A or Class B pathogen standards.

Typically, MSW is spread at the working face of the landfill and then the biosolids are mixed with the MSW with conventional landfill equipment. The ratio of MSW to biosolids is typically 9:1, but depends strongly on the solids content of the biosolids (U.S. EPA, 2003c). Placement of biosolids within the landfill volume eliminates the potential for their reuse. However, biosolids are sometimes mixed with soil and used to cover the refuse at the end of the working day, as intermediate cover between landfill cells, or to promote vegetative growth in the final cover material when a section of landfill is being closed. The later activity might more properly fall under the category of land application, since the biosolids are used to enhance growing conditions for cover vegetation.

Landfill disposal is often selected when land application is deemed too expensive or not feasible due to land acquisition constraints. Biosolids that do not meet the pollutant limits or stabilization requirements for land application are usually landfilled. Highly odorous materials, which might otherwise create a public nuisance when spread on the land, are managed by landfilling. However, such materials can also be problematic for landfill disposal when off-site odors are an issue.

Incineration

Incineration is the drying and combustion of dewatered wastewater solids that results in a relatively inert ash. Typically 65 to 75 percent of the solids are combustible and therefore the volume of the ash is generally only one-quarter that of the original

material. Ash is generally landfilled in Pennsylvania, although at least one facility has Pennsylvania Department of Environmental Protection (DEP) approval to land apply biosolids incinerator ash. Incinerator ash can also be used as a component in cement, brick production, asphalt paving mixes, or manufactured soils.

In 2003, there were only 254 incinerators (of about 16,000 WWTPs) for wastewater solids operating in the United States (EPA, 2003b). Incinerators involve high capital and operating costs and require highly trained employees. They tend to be more economical for facilities with capacities greater than about 10 million gallons per day, and thus are rarely found in rural communities. Wastewater solids incinerators are regulated under the Clean Air Act Amendments of 1990, and if the ash meets the definition of a hazardous waste, appropriate federal regulations must be followed for its disposal. The ash from biosolids-only incinerators rarely qualifies as a hazardous waste.

Surface Disposal

The Part 503 Biosolids Rule also provides standards for "surface disposal" of biosolids. This term refers to permanent disposal or long-term storage of sludge in uncovered lagoons or impoundments. Management requirements include provisions for runoff collection, vector control, and restrictions on public access, growing of crops, or grazing animals. Sometimes storage is part of the overall biosolids management plan. Winter storage is needed until weather conditions allow land application. Storage reduces water content and therefore decreases hauling costs. In addition, small facilities may store solids to accumulate quantities sufficient for disposal or recycling. In some cases, solids are stored on site without any definite timetable for removal.

BIOSOLIDS USE AND DISPOSAL

Data on the disposal of biosolids nationally and in Pennsylvania are limited. EPA estimated that 6.9 million tons of biosolids were generated in 1998, of which 60 percent were used through various land application practices (agricultural, reclamation, horticultural), 22 percent were disposed by incineration, 17 percent managed by landfilling or surface disposal, and 1 percent disposed in some unidentified manner. Of the amount being used for land application, 87 percent did not receive advanced treatment (thermal treatment/pelletization, composting, lime stabilized) and thus would be considered Class B products. In 1999, EPA estimated that the percentage of biosolids managed for beneficial use would increase to 66 percent by 2005 and to 70 percent by 2010. These projections were based on the prediction that landfill disposal would decrease due to cost and siting considerations.

A 1999 national survey of biosolids management practices by Goldstein and Block (1999), which gathered information from state regulatory officials, found that 71 percent of biosolids in Pennsylvania were beneficially used (land application and composting), 24 percent were landfilled, and 5 percent were incinerated. According to DEP (Tropea, 2000), in 2000, about 58 percent of biosolids produced in Pennsylvania were recycled to land (agricultural and mined) with the remainder predominantly landfilled (27 percent) or incinerated (15 percent). A few systems involve distribution and marketing of biosolids derived products that have been processed to meet exceptional quality regulatory requirements. Much of this material is also land applied through horticultural and landscaping applications.

The Part 503 Rule and Pennsylvania regulations allow for numerous biosolids management options, and communities decide which options are appropriate for them. Cost is clearly one of the most important factors in the decision-making process. Definitive ranking of biosolids management costs is hampered by the number of options in the wastewater solids management chain and the multiplicity of factors that influence program costs such as electrical power, labor, hauling distance and facility size. Despite the complexity and variability in biosolids management methods, the literature does contain some general statements about the cost differentials among land application, landfilling, and incineration.

Data collected for the development of the Part 503 Rule indicated that surface disposal and cropland application were the least expensive biosolids management options (EPA, 1999). Monofilling of biosolids was about 20 percent more expensive than application to land. Landfilling in municipal solid waste landfills has generally increased in cost disproportionately compared to other methods because of the additional constraints imposed by the municipal solid waste landfill regulations (EPA, 1999). The cost advantage of land application over landfill disposal is particularly apparent in communities where disposal costs have risen in response to diminishing landfill capacity (NBP, 2005). According to a bulletin prepared by Virginia (Evanylo, 1999), land application of biosolids costs less than half that of landfilling. The Clearfield (Pennsylvania) Municipal Authority operates a biosolids land application program that has saved borough taxpayers about $45,000 a year compared to landfilling (Tropea, 2000). While landfilling is generally more costly than land application, the EPA notes that landfilling costs in some areas are very inexpensive due to construction of very large landfills, called "megafills" (EPA, 1999).

Incineration is one of the most expensive biosolids management options on a unit cost-per-ton basis (EPA, 1999). Incineration involves a significant initial capital cost, and the Part 503 Rule continuous monitoring requirements for incinerators contribute to high operational costs (EPA, 2000). Because the ash is generally landfilled, there are final disposal costs also associated with incineration. For facilities less than 10 million gallons per day in capacity, land application and landfilling are usually more economical (EPA, 1986).

PROJECT OBJECTIVES AND METHODOLOGY

INVENTORY OF BIOSOLIDS DISPOSAL PRACTICES IN PENNSYLVANIA

To evaluate current biosolids management practices in Pennsylvania, the researchers used a multiple-step approach. Initially, biosolids-generating facilities were inventoried using EPA and DEP databases. Facilities were stratified based on treatment capacities in millions of gallons per day: small (<1 million gallons per day), medium (1-5 million gallons per day), and large (>5 million gallons per day). Using the Center for Rural Pennsylvania's population-density-based definitions, biosolids management practices were also delineated according to rural or urban county facility location[1]. Practices were evaluated based on both the number of facilities using each disposal method and the quantities of materials disposed by each method. The EPA database served as a starting point and was modified based on information gathered from the regional and central offices of DEP. A facility survey was sent to all Pennsylvania WWTPs holding a National Pollutant Discharge Elimination System (NPDES) permit. Survey responses and personal contacts with WWTPs and consulting engineers were also used to arrive at the final distribution inventory.

CLEAN WATERSHED NEEDS SURVEY

The Clean Watershed Needs Survey (CWNS) was a collaborative effort between EPA and the lower 48 states in response to heightened concern over sections 205(a) and 516 of the Clean Water Act (CWA) (EPA, 2003a). EPA conducted the CWNS in 1996 and again in 2000.

The CWNS provides individual facility data such as flow, population receiving collection, treatment processes, and effluent disposal for all publicly owned wastewater treatment facilities (EPA, 2003a). The information from the facility fact sheets was used to create an overall database with listings of the population served, flow, county, primary treatment process, CWNS number, and longitude/latitude for each treatment facility. This information was used to calculate annual solids production rates and create geographic information system (GIS) location maps of wastewater treatment facilities in Pennsylvania.

PENNSYLVANIA DEP RESOURCES

DEP provided a list of facilities that have been granted a permit to land apply biosolids. This information also lists the facilities that have exceptional quality biosolids production processes as well as haulers that have been approved to transport and land-apply biosolids. The six regional DEP offices were also contacted to obtain a current list of WWTPs that incinerate their wastewater solids.

CURRENT INVENTORY

A survey of WWTPs and personal contacts were made to verify or update solids disposal methods reported in the CWNS database. Contacts were either employees of the WWTPs or consulting engineers who have worked for or are familiar with the facilities. This helped to determine the principal disposal practice currently being used and helped clear up any confusion with facilities that list more than one disposal method. In addition, if a facility currently uses more than one disposal method, the quantities allocated to each method were included in the quantity-based distribution analysis.

ESTIMATING SOLIDS PRODUCTION RATES

Estimates were made to determine the quantity of biosolids (dry tons per year) being produced by each facility and were compared between size classes and disposal methods. The estimates were based on the average daily flow rates taken from the CWNS and typical wastewater solids production values. In its national survey, EPA (EPA, 1999) defined the biosolids generation factor as the dry tons of biosolids generated annually for a wastewater facility treating 1 million gallons of wastewater per day. The biosolids generation factor of 206 is given for WWTPs employing secondary treatment. Thus, using the daily flow rates from the CWNS, the annual biosolids production for each facility can be estimated. EPA presented arguments for why this number might be high or low, some of which would apply to WWTPs in Pennsylvania. While some facilities in the commonwealth will produce more solids because of greater chemical dosages (e.g., for lime stabilization), and some facilities produce less biological solids because of the nature of the treatment processes (e.g., extended aeration), this value was taken as representative for the overall quantification of biosolids generated within the state.

GEOGRAPHIC DISTRIBUTION OF BIOSOLIDS MANAGEMENT PRACTICES

A GIS was used to display the spatial distribution of solids management practices for the facilities in the database. Facilities were plotted based on their latitude-longitude coordinates, and their county location was designated as rural or urban based on the Center for Rural

[1] A county is considered rural when the number of persons per square mile within the county is less than 274. Counties that have 274 persons or more per square mile are considered urban.

Pennsylvania's population-based definitions. While incineration is conducted at the WWTP facility, facilities transport solids for both land application and landfilling. Therefore, this method does not pinpoint precisely the location of the disposal or recycling activity. However, because overall cost is a strong function of hauling distance, facilities tend to dispose or recycle biosolids as close as possible to their facility. Facilities that routinely use more than one solids management technique have their locations shown on multiple maps.

STATEWIDE SURVEY OF BIOSOLIDS MANAGEMENT PRACTICES

A survey was developed and sent to WWTPs in Pennsylvania having an NPDES permit. The NPDES program was set up under the CWA to regulate all point sources that discharge pollutants into the waters of the U.S. Because some facilities have more than one NPDES permit (e.g., for stormwater and other non-WWTP discharges), the number of surveys mailed (870) was greater than the actual number of operating WWTPs in the state. According to DEP (2004b), there are "more than 700 municipal wastewater treatment facilities across the commonwealth." The CWNS database lists 640 WWTPs and serves as the basis of this analysis. The difference between the CWNS list and the estimated number from DEP likely reflects new, small facilities that were not included or have come on line since the original CWNS database (EPA, 2003a). The survey requested information on solids handling processes, biosolids disposal or recycling practices, and costs related to biosolids management. Besides providing important information for the current inventory, the primary survey goal was to collect facility information to compare the costs of alternative biosolids management strategies across the commonwealth. Because reliable cost comparisons require a consistent methodology for inclusion of components and calculating costs, the survey addressed off-site handling costs for biosolids management. Three weeks after the initial survey mailing, a reminder post-card was sent to non-respondents.

BIOSOLIDS DISPOSAL COSTS

Survey results provided information on the biosolids management costs for each facility. Since landfill tipping fees and solids management contract costs are quoted on a wet-weight basis, information on final moisture content of biosolids was used to convert costs to a dry-ton basis. The dry mass of solids produced was used to calculate the costs of operations (e.g., trucking, landfilling, land application) directly related to the disposal of the solids. Distance to final location was also requested in the surveys so that total off-site handling costs could be calculated for WWTPs that use municipal resources for transporting wastewater solids.

RESULTS

INVENTORY OF BIOSOLIDS MANAGEMENT IN PENNSYLVANIA

Current biosolids management practices in the state were quantified by updating the information provided in EPA's CWNS, published in 2003. Three primary sources allowed for a current assessment: information provided by DEP, personal contacts with wastewater professionals, and a survey sent to municipal facilities in Pennsylvania. The data were analyzed and compiled based on the number of facilities, the quantity of solids generated, and the rural-urban distribution of WWTPs.

FACILITY-BASED DISTRIBUTION

Table 1 shows the statewide distribution of WWTPs based on the principal method of solids management. The most accurate category numbers are those presented for the large facilities, as management practices were individually verified for the largest 55 facilities in the state. This group includes all facilities with flow rates over 3.7 million gallons per day and encompasses 19 facilities that fall into the medium category, according to the CWNS database. Because the largest facilities exert a disproportionate influence on the overall biosolids management picture, it was important to know their management practices with certainty.

Table 1. Number of WWTPs Employing Land Application, Landfilling, and Incineration

Method	<1 MGD	1-5 MGD	>5 MGD	Total
Land Application	104	42	13	159
Landfill Disposal	349	108	16	473
Incineration	0	1	7	8
Total	453	151	36	640

The management practices for small facilities are more difficult to define with precision. Some small facilities have storage lagoons or drying beds that are considered "permanent" storage because they may be emptied very infrequently. Such facilities do not have yearly contracts for solids disposal given the infrequent need to provide ultimate disposal of their solids. Moreover, of the 172 small facilities that responded to the survey, 51 (30 percent) indicated that solids were sent to another (presumably larger) WWTP facility for final disposition. One small WWTP reported that their solids were incinerated at another facility, but for the most part, these "receiving facilities" practice landfilling or land application.

Figure 1. Percent distribution of disposal methods for WWTPs in three size categories and for all facilities.

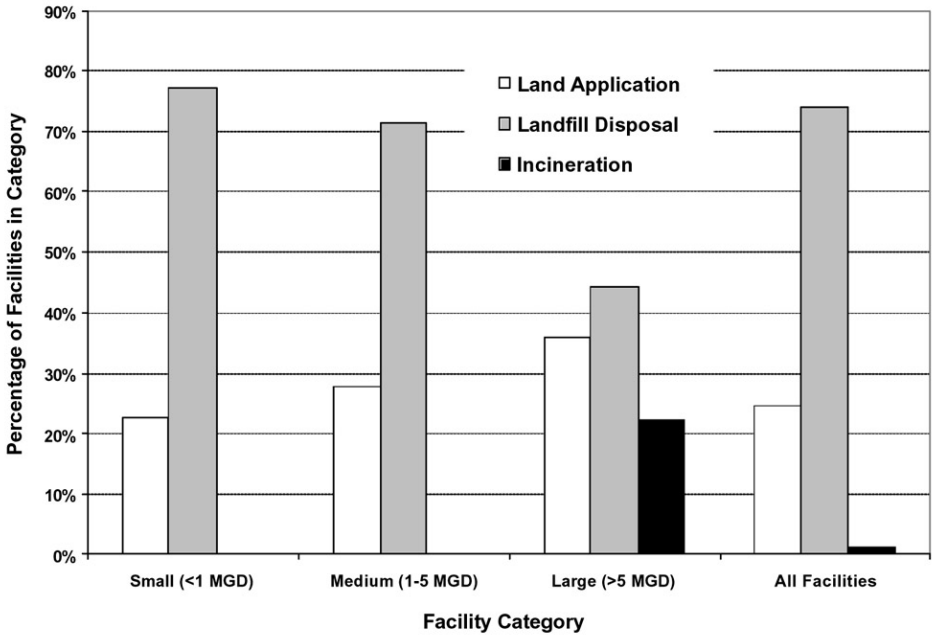


Figure 1, based on Table 1, shows the percent usage of the three management practices based on the WWTP size categories. It is notable that, overall, about three-fourths of the WWTPs in the commonwealth rely on landfilling for solids disposal. While this is primarily a non-reuse practice, some biosolids in this category are used to amend final cover material when a landfill cell is closed after reaching capacity. Here the biosolids are used to enhance the fertility of the cover soil and promote vegetation establishment and sustenance. This type of landfilling could be logically considered a form of beneficial use of land application. While the survey instrument distinguished between landfill disposal and landfill beneficial use, the CWNS database did not. Hence, an accurate quantification of landfill beneficial use was not possible. This said, only two survey respondents reported landfill beneficial use.

QUANTITY-BASED DISTRIBUTION

Annually, over 300,000 dry tons of wastewater solids are generated by WWTPs in Pennsylvania (Table 2). This figure is strongly dependent on the estimated amount of wastewater solids produced for a given quantity of treated wastewater. This analysis used the EPA biosolids generation factor (EPA, 1999), based on extensive long-term data collection. Using the number of facilities practicing each method from the current analysis, the quantities of solids recycled or disposed by the three methods were calculated.

RURAL-URBAN DISTRIBUTION

Of the 640 WWTPs in the CWNS database, 336 and 304 are located in rural and urban counties, respectively. The WWTPs designated as urban have an average capacity of 4.0 million gallons per day. The average capacity of the rural WWTPs is 0.74 million gallons per day, with 80 percent having flow rates of 1 million gallons or less per day. Although there is no one-to-one correspondence between the rural facilities and those designated as "small" by capacity, about 60 percent of the facilities in the small category are located in rural counties. Only five "large" facilities (> 5 million gallons per day) are located in rural counties.

Management practices based on the rural-urban facility location are given in Table 3. All three management options are practiced in both rural and urban WWTPs; however, there are some notable differences. Rural WWTPs as a group rely predominantly on landfilling, with more than 80 percent of facilities employing this disposal option. Only one of eight biosolids incineration facilities in the state is in a rural county. The corresponding rural quantity-based distribution is therefore non-uniform and skewed toward landfilling. In marked contrast, appreciable quantities of biosolids from urban WWTPs are handled through all three major methods.

An interesting feature of the data is the greater predominance of land application used by urban compared to rural WWTPs. Nearly 18 percent of the rural facilities employing land application account for 28 percent of the total solids production confirms that it is the larger rural facilities that have the resources to maintain a land application program.

SPECIFIC MANAGEMENT PRACTICES

The following is a discussion of survey information that provides a more detailed picture of statewide biosolids disposal and recycling.

CLASS A PROCESSING

In response to the survey instrument, 37 facilities reported producing Class A biosolids products. Closer examination revealed that six responding WWTPs export their solids to other treatment facilities. Another 15 WWTPs (13 with <1.0 million gallons per day average daily flow) provided no information supporting their

Table 2. Dry tons of biosolids produced per year by facility size and disposal method.

	Annual Biosolids Management Quantities (dry tons)
Landfill	
Small	19,700
Medium	45,000
Large	76,300
Total	141,000
Land Application	
Small	8,200
Medium	20,900
Large	87,600
Total	116,700
Incineration	
Small	-
Medium	1,000
Large	45,000
Total	46,000
TOTAL	303,700
Landfill	46.4 percent
Land Application	38.4 percent
Incineration	15.2 percent

assertion for Class A biosolids processing. Since most of these plants indicated landfill disposal as their ultimate disposal option and were categorized as small plants, the researcher concluded that Class A processing was unlikely at these facilities. Thirteen WWTPs provided survey information supporting conventional Class A biosolids processing for which operational standards are defined by state and federal regulations: four composting; five advanced-alkaline stabilization; three thermal drying (one in operation, one in startup, and one under construction), and one autothermal thermophylic aerobic digestion (ATAD) facility. Three additional facilities reported Class A processing by reed bed (two small plants) or vermicomposting. Documentation of Class A treatment by reed bed or vermicomposting, at present, requires testing of each "batch" to confirm adequate pathogen reduction. Some respondents indicated Class A products were being generated, but did not provide supporting process information. Direct contact with some of these facilities indicated that the generated biosolids were, in fact, Class B products. Thus, a total of 16 WWTPs out of the 280 survey respondents (approximately 6 percent) provided information clearly indicative of Class A processing. The total weight of biosolids processed by these Class A facilities is estimated at 25,000 dry tons per year, or about 8 percent of Pennsylvania's total WWTP solids production.

RECLAMATION

Only five facilities (two small, two medium, and one large) responded that their biosolids were used for reclamation. Discussions with DEP officials engaged in mine land reclamation in Centre and Clearfield counties indicated that the biosolids used currently, and in the recent past, for the most part originate in New York and New Jersey. Biosolids generated within the state are being used in reclamation activities in Schuylkill County. Based on this limited information, it is difficult to quantify the exact amount of state-generated biosolids being used for land reclamation activities in the commonwealth.

DISPOSAL AT ANOTHER FACILITY

A number of small and medium facilities transfer their solids to other wastewater treatment plants for treatment, followed by disposal or beneficial use. This method of solids management does not fit neatly into the overall categorization scheme. For the small facilities, 51 of 172 respondents (30 percent) indicated this solids handling option; and nine of 82 (11 percent) medium-sized WWTPs transport solids to another facility. The quantity-based biosolids distribution reported in this study was interpreted from updated CWNS data and the researchers assume the receiving facility employs the same biosolids

Table 3. Biosolids management methods, based on location, as a percentage of facilities and total solids production in each category.

Method	RURAL		URBAN		ALL	
	% facilities	% total solids produced	% facilities	% total solids produced	% facilities	% total solids produced
Land Appl	17.6	28.1	33.2	40.5	24.8	38.4
Landfilling	82.1	69.9	64.5	41.7	73.9	46.4
Incineration	0.3	2.0	2.3	17.8	1.3	15.2

management option as reported by the exporting facility. Errors in this assumption do not have any serious impact on the quantity-based distribution (Table 2) since these facilities do not generate large quantities of solids.

Small WWTPs that send their solids to another facility for processing (51 of 172) reported paying between $100 and $200 per 1,000 gallons for disposal at another WWTP. Some of these small facilities apparently have no dewatering equipment. Given that they are paying for solids removal on a volume (gallon) basis, further concentration of solids through dewatering would likely be cost effective for some facilities.

LONG-TERM STORAGE

Some facilities could not provide current cost information for solids disposal because it occurs so infrequently or is effectively considered to be an on-site activity. Several small facilities reported using reed beds and long-term storage lagoons. Such practices are only possible where the WWTP generates small quantities of solids and the plant site has adequate storage to accommodate the solids. Because they rely on solar drying for dewatering, these practices generally have low operating costs. Solids removal occurs only intermittently as needed. In the case of reed beds, a clean-out frequency of up to 10 years was reported.

STATEWIDE DISTRIBUTION OF MANAGEMENT PRACTICES

Figures 2, 3, and 4 show the locations of the WWTPs practicing land application, landfill disposal, and incineration, respectively. While incineration is conducted at the WWTP facility itself, off-site transport of solids is required for both land application and landfilling. Therefore, the methodology does not precisely pinpoint the location of the disposal or recycling activity. However, because overall cost is a strong function of hauling distance, facilities tend to dispose or recycle biosolids within 20 miles of their facility. Facilities that routinely use more than one solids management technique have their locations shown on multiple maps.

The maps reflect biosolids disposal methods of facilities in Pennsylvania, but this cannot be directly translated into the quantities actually disposed within the state. Significant quantities of biosolids are

Figure 2. WWTPs employing land application.

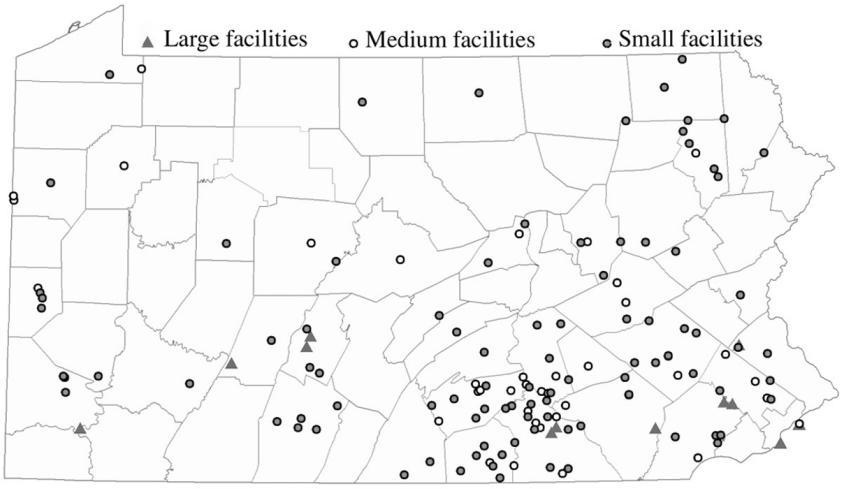


Figure 3. WWTPs employing landfill disposal.

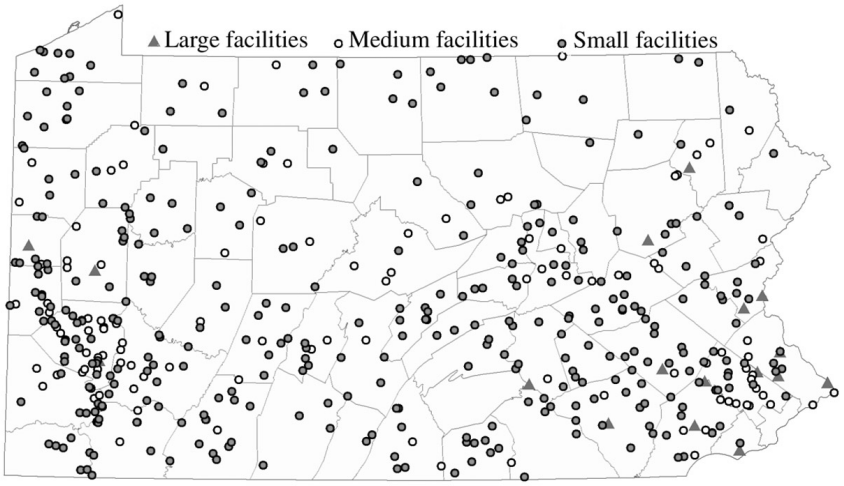
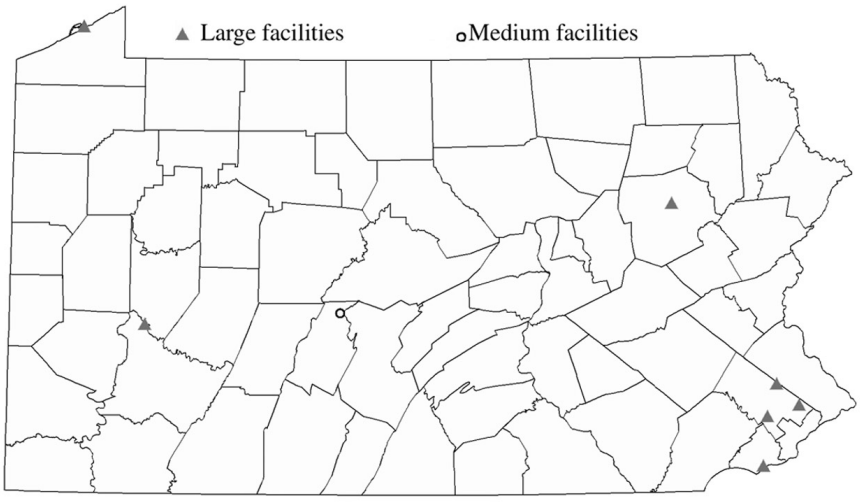


Figure 4. WWTPs employing incineration.



transported across state boundaries. While landfilling of Pennsylvania-generated biosolids seems to occur primarily within the state, survey results and direct contacts indicate that an appreciable quantity of biosolids generated within Pennsylvania are land applied in neighboring states. Companies that contract with WWTPs to recycle their biosolids transport them to Virginia, New Jersey, Ohio, and Maryland. Biosolids from neighboring states are landfilled within Pennsylvania. Accurate quantification of out-of-state biosolids disposal is difficult because surveyed facilities are often unaware of the final disposal location when these services are outsourced to a contractor.

Table 4. Average cost per dry ton for beneficial use/ disposal of WWTP solids by facility size.

	Land Application	Landfill
Small Facilties (<1 MGD)		
# Observation	24	58
Average cost per dry ton	$252.00	$280.35
Medium Facilities (1 TO 5 MGD)		
# Observation	13	39
Average cost per dry ton	$201.65	$256.08
Large Facilities (>5 MGD)		
# Observation	14	19
Average cost per dry ton	$145.16	$260.32

MGD=Million gallons per day

Landfill disposal is common over the entire state, with clusters in the more populated areas. In marked contrast, land application of biosolids tends to be primarily focused in the southeastern and south-central regions of the state, in counties that have excess nutrients (nitrogen and phosphorus) from livestock production. Biosolids contain similar levels of nitrogen and phosphorus to livestock manures and are normally land-applied in conventional crop production systems. Thus, it is not surprising that most biosolids tend to be spread in counties with significant agricultural operations. The few biosolids incinerators tend to be concentrated in counties at the four corners of the state: Erie, Westmoreland, Montgomery, Delaware and Luzerne.

BIOSOLIDS MANAGEMENT COSTS

LANDFILLING AND LAND APPLICATION

Biosolids management costs have two major components: the actual dollar costs associated with capital and operating expenses, and the more subjective component that deals with the value of resource recycling and the costs of environmental risks. Quantitative results reported in this analysis address the former costs, and focus specifically on direct management costs associated with final disposition of solids captured in municipal wastewater treatment.

From the survey responses, 168 facilities provided meaningful information for developing overall biosolids management cost trends. The distribution of cost information based on facility size was small facilities (83), medium facilities (52), and large facilities (23). The most precise cost figures were provided by facilities that pay contractors to landfill or land apply biosolids on an "out-the-door" cost per wet ton basis, that is, the contract price includes both transportation and disposal or recycling costs. For facilities that use municipal equipment to haul solids to the site for ultimate disposition (landfill or application site), two assumptions had to be made to estimate transportation costs. The capacity of the hauling vehicle was assumed to be 15 cubic yards. For a given solids content, the dry tons per truckload were then calculated. Based on estimates for personnel cost, fuel, and maintenance of municipal operated trucks, the cost was set at $3 per mile. Respondents were asked to provide the mileage from the facility to the landfill or land application site.

The cost of landfilling biosolids was found to be quite variable across the state. Garvey (2005) noted that bid specifications for hauling and landfill disposal of biosolids have increased 35 percent to 50 percent in the eastern part of Pennsylvania. Several reasons are cited. DEP approval for expansion of existing landfills have been denied or postponed. In addition, the closing of large landfills near New York City and in northern New Jersey has increased demand for landfill space in Pennsylvania. Haulers are willing to pay higher tipping fees because disposal in western Pennsylvania, Ohio or Virginia requires long hauling distances. One facility reported a quid-pro-quo arrangement with a landfill: in exchange for the right to dispose of wastewater solids in the landfill, the wastewater treatment plant accepts and treats leachate from the landfill.

INCINERATION

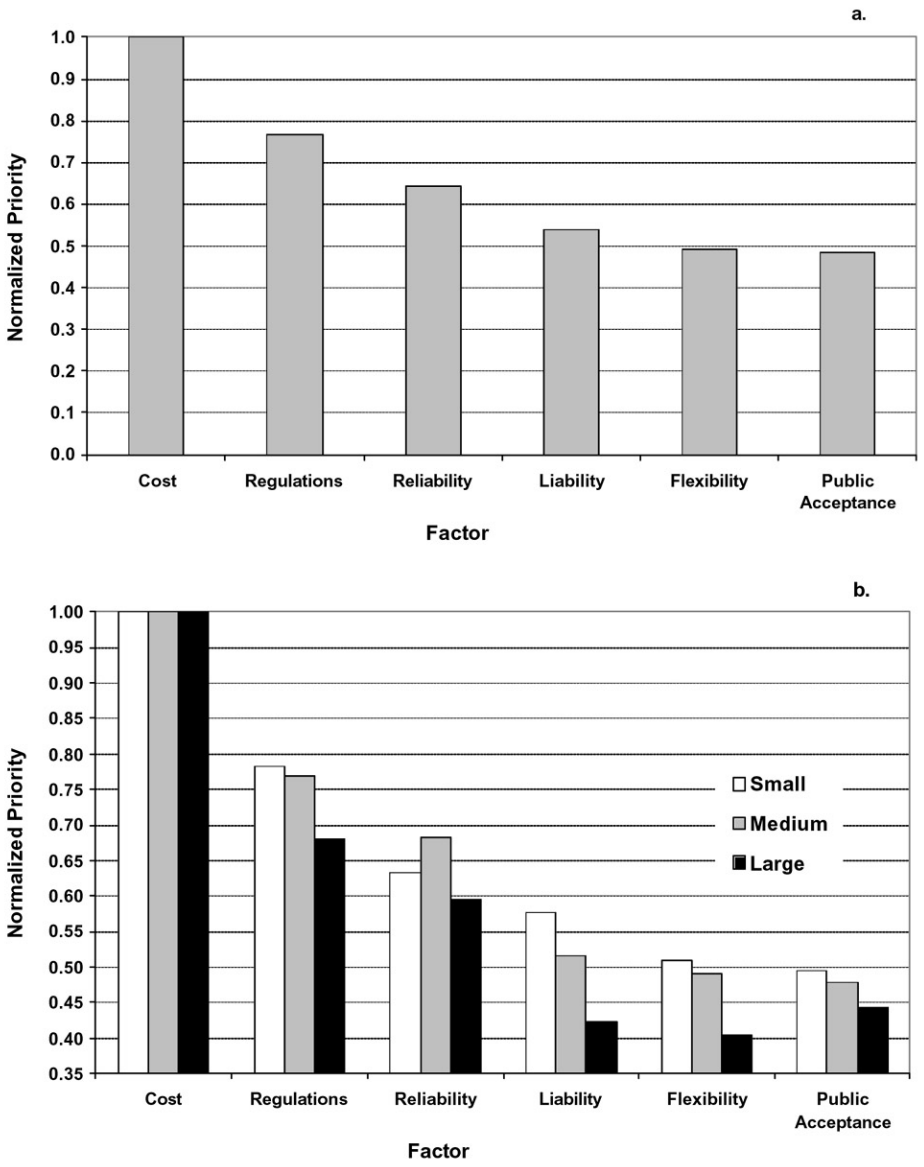
This study identified only eight facilities in Pennsylvania that have biosolids incinerators and limited useful information was gathered on incineration costs. The reported cost for incineration is based on figures provided by EPA and other sources deemed reliable. Because of high capital investment and sophisticated operational requirements, incineration seems to be almost exclusively confined to large facilities (>5 million gallons per day). Indeed, in Pennsylvania, apparently no facilities in the small (<1 million gallons per day) category incinerate biosolids. Only one WWTP in the medium (1-5 million gallons per day) category has the equipment to incinerate wastewater solids. Its

capacity is under 5 million gallons per day, and thus this WWTP is almost in the large facility category. This is also the only incineration facility located in a rural county (Blair). Another medium-sized facility responding to the survey indicated they transport their solids to a larger facility with an on-site incinerator. Nonetheless, the economics of biosolids incineration has limited impact on rural communities.

Facilities that incinerate biosolids typically take the residual ash to a landfill for ultimate disposal. In contrast to land application and landfilling, however, the cost of transporting the ash and the ultimate disposal fee (i.e., tipping fee) represent a very small portion of the total solids management costs. First, the ash material is nearly bone dry, meaning that there is little cost of hauling compared to biosolids that may be 80 percent to 85 percent moisture. Additionally, the combustion process removes 70 percent to 80 percent of the mass of the wastewater solids so that a small percentage of the dry weight of biosolids produced at the facility are actually removed from the site as ash. Dangtran et al. (2000) reported ash disposal for biosolids incinerators to cost between $2 and $12 per dry ton, representing 1.7 percent to 5.7 percent of the total cost of managing biosolids using incineration.

According to EPA (2003b), the operation and maintenance costs for multiple hearth facilities with air pollution control equipment to meet the Part 503 Rule regulations are approximately $244 per dry ton of biosolids. A detailed cost analysis of a 140 million gallons per day facility conducted by McMillon et al. (2000) found the cost of biosolids incineration was $292 per dry ton. NEBRA (2001) quotes the cost of contracted incineration at $55 to $90 per wet ton, which, assuming a feed solids content of 25 percent solids (EPA, 2003b), translates into $220 to $360 per dry ton of biosolids. Given the other cited costs for incineration, the average value of this range ($290 per dry ton) seems to be a reasonable estimate of the cost of incineration. This value, compared to the figures in Table 4, also supports the notion that land application and landfilling are usually more economical for smaller wastewater treatment plants (EPA, 1986; EPA, 1999).

Figure 5. Relative priority of factors affecting selection of Pennsylvania WWTP solids management: a. all responding facilities; and b. small, medium, and large facilities.



FACTORS INFLUENCING MANAGEMENT PRACTICES

The survey asked respondents to rank six factors (cost, flexibility, reliability, public acceptance, regulatory requirements, and liability concerns) in terms of importance in influencing selection of biosolids disposal or reuse method(s) at their wastewater treatment facilities.

Of the 280 surveys returned, 240 respondents provided rankings of all six factors. Figure 5 shows the priority ranking for all facilities by facility size in the following order: cost, regulatory requirements, reliability, liability, flexibility, and public acceptance. The prominence of cost is not surprising; municipalities must operate within budget constraints and affordability is an important consideration. Regulatory requirements were also ranked highly, and several of the surveys contained comments about the regulatory "hurdles" associated with land application of biosolids. Notably, public acceptance was considered to be the least important of the six factors.

Relative to cost, several of the factors appear to be inversely related to facility size. For example, small WWTPs seem to be more concerned than large facilities about the potential liability, regulatory requirements and public acceptance of their biosolids management practices. Interestingly, these small facilities also see flexibility as significantly more important than large facilities. While summary data of this type is important for gauging the industry-wide importance of factors in decision-making, it should be understood that local conditions and factors may dictate a very different priority ranking for an individual facility.

CONCLUSIONS

Database evaluation and facility survey results reveal the complexity and variety of options for management of wastewater biosolids in Pennsylvania. This section provides a synthesis and discussion of the project results and compares current statewide management with past practices and national and regional trends. Finally, a rationale is offered for future directions in biosolids management practices in the commonwealth.

BIOSOLIDS MANAGEMENT PRACTICES

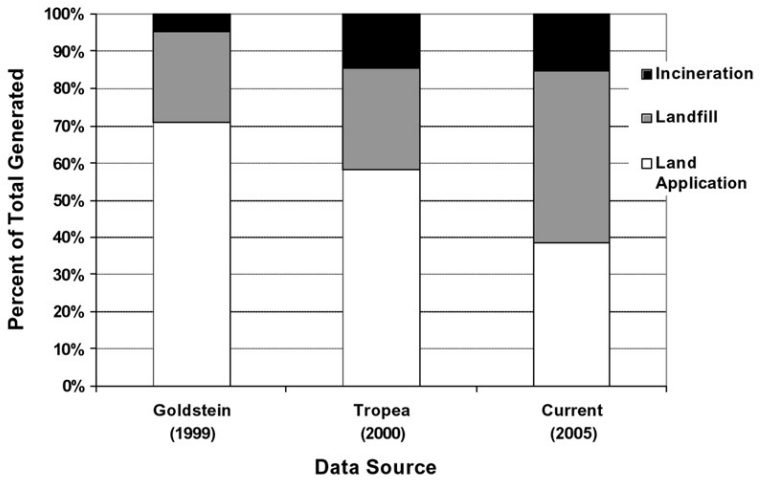
STATEWIDE DISTRIBUTION OF METHODS AND FACILITIES

Figure 6 compares the results of this study with two previous reports on the distribution of biosolids disposal methods in Pennsylvania. The survey conducted by Goldstein and Block (1999) was based on information provided by state officials and covered all states, not just Pennsylvania. Their study concluded that 60 percent of the total biosolids generated in Pennsylvania were land applied but an additional 10 percent were composted and 1 percent was heat dried or pelletized. Since composted and pelletized biosolids are typically land applied, the figure of 71 percent is shown in Figure 6. According to Goldstein and Block (1999), only 5 percent of the biosolids generated in the state were incinerated, with 24 percent were landfilled.

Because the Goldstein and Block (1999) survey was national and not Pennsylvania specific, the distribution cited by Tropea (2000) is believed to be a more reliable, albeit dated, picture of practices in the commonwealth. Tropea (2000) reported 15 percent of the state's biosolids were incinerated, a figure that agrees with the current analysis. However, the estimate of 58 percent for land application is substantially higher than the 38.4 percent determined in this study. Since the percentage of biosolids incinerated is comparable in both distributions, the smaller percentage attributed to land application in the current analysis is accompanied by a proportionate increase in the landfilling category.

Comparison of the current evaluation to the 2000 DEP estimates suggests that biosolids incineration, as a percentage of the total amount generated in the state, has not changed markedly in the past five years. The researchers estimated 46,000 dry tons of biosolids (15.2 percent of total) are currently incinerated (Table 2), while Tropea indicated 58,000 dry tons (14.7 percent of total) were incinerated five years ago. What has changed significantly over the past decade is the number and size distribution of facilities that incinerate biosolids. The 1996 EPA CWNS (2003a) listed 23 facilities in the state having multiple hearth biosolids incinerators. These facilities were in the small, medium, and large size categories. Currently, however, only eight biosolids incinerators operate around the state, all operating at facilities with flow rates of five million gallons or more per day. This reduction in the number of biosolids incinerators is consistent with the national trend. According to EPA (EPA, 2003b), the number of biosolids incinerators dropped from 343 in 1993 to 254 in 2003 nationally. Apparently, increasingly stringent air pollution control requirements of the Clean Air Act could not be met

Figure 6. Comparison of quantity-based biosolids management methods.



with multiple hearth incinerators and many were shut down. Given the tremendous capital cost for constructing incinerators and associated air pollution control equipment, the number of biosolids incinerators is not likely to grow in the near future. The amount of biosolids disposed by incineration could increase if existing incinerators were fed wastewater solids from treatment plants in surrounding communities.

Most striking is what appears to be a trend away from beneficial reuse accompanied by a proportional increase in landfill disposal. Of the 49 states reporting in the Goldstein and Block (1999) survey, 29 indicated that beneficial use of biosolids was on the rise. Pennsylvania was not one of these states. However, neither was Pennsylvania among the seven states reporting an increasing trend toward landfilling (Goldstein and Block, 1999). At the same time of the Goldstein and Block survey, EPA (EPA, 1999) estimated that the percentage of biosolids managed for beneficial use would increase nationwide from 60 percent (1999) to 66 percent by 2005 and to 70 percent in 2010. These projections were based on the prediction that landfill disposal would decrease due to cost and siting considerations. This pressure to move toward beneficial use in response to escalating landfilling costs apparently has not been realized in Pennsylvania. In fact, there is a high concentration of facilities that land apply biosolids in the south-central portion of the state, which coincides with an area of relatively low landfilling costs.

Because evaluation of Tropea (2000) was based on only 259 Pennsylvania facilities that provided data to EPA in 1998, the conclusion that beneficial reuse is decreasing in Pennsylvania should be approached with caution. Regardless of the actual direction of biosolids management practices in the state, this study does not support the widespread perception that land application is the most common ultimate fate of wastewater solids generated in the commonwealth. In fact, this study revealed several factors that encourage municipalities to prefer landfilling over land application.

Biosolids professionals report that landfilling costs dropped in the late 1990s, encouraging some facilities to switch to this disposal method. The continuing low tipping fees, particularly in western Pennsylvania, encourage municipalities to choose landfilling as the preferred biosolids management option. Expediency is another factor that encourages municipalities to choose landfilling over land application. Land application requires storage or alternate management options during periods of unsuitable weather or cropping restrictions, tighter odor control measures, and public outreach efforts. The net effect is a much simpler switch from land application to landfilling than vice versa. Facilities also cite liability, lack of public acceptance, limited personnel, decreasing agricultural land base, and burdensome regulatory requirements as disincentives for recycling biosolids via land application.

GEOGRAPHIC DISTRIBUTION

Based on the number of facilities practicing each method, landfilling is by far the most common strategy for biosolids management. Landfill disposal is common over the entire state, with clusters in the more populated areas particularly around Allegheny County. Despite higher landfilling costs in the eastern part of the state, many municipalities in this region also landfill their biosolids.

In marked contrast, land application of biosolids tends to be primarily focused in the southeastern and south central regions of the state, in counties that have a large amount of agricultural land. These counties also tend to have excess nutrients (nitrogen and phosphorus) from livestock manures. Bakner (2005) reported that 51 percent of the total state land-applied biosolids are spread within the boundary of the Chesapeake Bay. This may have implications for Pennsylvania's Chesapeake Bay Tributary Strategy aimed at reducing nitrogen and phosphorus from point and non-point sources in the Susquehanna and Potomac River basins. All WWTPs with average flow rates greater than 0.4 million gallons per day are required to reduce the nitrogen and phosphorus levels in their effluent to 8.0 and 1.0 mg/l, respectively, by 2010 (Lusardi and Reese, 2005). When effluent nitrogen and phosphorus levels are reduced, biosolids nutrient content increases accordingly. The proposed strategy requires new municipal or non-municipal WWTPs to meet zero net additions of nitrogen and phosphorus. This can be done through the purchasing of nitrogen/phosphorus reduction credits from other WWTPs (Volkay-Hilditch, 2005). The Nutrient Trading Program enables the transfer of pollution reduction credits. WWTPs can generate credits by reducing nitrogen and phosphorus below requirements, and these credits can be sold to other generators to meet goals (Lusardi and Reese, 2005).

The few biosolids incinerators tend to be scattered around the state and located in major population centers. Four of the 10 largest WWTPs in the state practice incineration and these are in counties roughly at the four corners of the state. These four facilities account for 90 percent of the incinerated biosolids in the state.

BIOSOLIDS MANAGEMENT COSTS

BENEFICIAL REUSE VERSUS DISPOSAL

The relative costs between land application and landfilling for biosolids management is influenced by many factors, such as hauling distances, tipping fees, pretreatment required prior to disposal, land availability, and size of the WWTP. There is a widespread opinion (EPA, 1999; DEP, 2004b; Evanylo, 1999) that land application is generally less expensive than landfilling. This seems to be supported by data in the literature. For Hampton Roads, Virginia, for example, the cost of hauling and landfilling of biosolids is $315 per dry ton,

compared to $174 per dry ton for land application (NBP, 2005). But the premise that land-based biosolids recycling is less expensive than landfilling is not universally accepted. According to the Michigan Department of Agriculture (MDA, 2005), "in most cases, landfilling is competitive or less expensive than land application. In some cases, U.S. communities have made a positive environmental decision to commit to recycling biosolids despite the additional cost. This is especially true where communities have committed to the additional costs of composting or heat drying biosolids prior to utilization."

Although the range of biosolids management costs reported in this study vary widely, the mean and median cost values in all size categories tend to corroborate the presumption that land application is less expensive than landfilling. Based on median cost per dry ton, land application is 60 percent to 90 percent of the cost of landfilling.

Because of economies of scale, there is an inverse relationship between community size and the cost associated with various biosolids management options. Although rural communities generate smaller quantities of solids, the unit cost for disposal is higher. Larger WWTPs have mechanical dewatering equipment so that operating and maintenance costs per dry ton are smaller than facilities that outsource the disposal of solids. Moreover, larger facilities can negotiate more favorable unit costs for landfilling and land application service contracts.

CLASS A PROCESSING

Facilities reporting some or all of their biosolids as Class A were not detailed enough to provide meaningful information on the cost differential between the cost of Class A versus Class B processing and recycling. The cost associated with common, conventional Class A processes (advanced alkaline stabilization, composting, and thermal drying) are highly variable due to the variety of technologies available and confounding factors relative to facility size, WWTP solids characteristics and quantities, land area requirements, odor related issues, capital versus operating and maintenance costs, end product quality requirements, marketability and sales revenue, and level of expertise required to successfully maintain and operate a Class A facility and associated distribution program. Some Class A options involve substantial capital costs (e.g., in-vessel composting), while others typically have lower capital costs but have high operating and maintenance costs (e.g. thermal drying). Hence, comparison of Class A treatment options is highly site specific and should include capital and operating and maintenance costs to get a realistic picture of the total cost to produce a dry ton of product.

McMillon et al. (2000) conducted cost comparisons of biosolids disposal practices for 19 facilities employing a variety of treatment processes and disposal practices, and some with multiple treatment trains and disposal options. Land application of Class B biosolids (five facilities) had an average cost of $344 per dry ton, while four facilities that land apply Class A biosolids had an average cost of $463 per dry ton. The cost differential between Class B and Class A is therefore $119 per dry ton. McMillon et al. (2000) conclude: "While some of the processes were higher cost than others, there were identifiable reasons for the difference in costs. Some of the differences were attributed to size of the facilities but most of the cost differentials were directly related to the processes that were utilized. In most cases, those processes were dictated by local conditions. As an example, some facilities required going from Class B to Class A biosolids. The increased cost in going from Class B to Class A is significant."

According to EPA (2002), capital plus operation and maintenance costs for biosolids composting range from $230 per dry ton (aerated static pile) to $405 per dry ton (in-vessel). In-vessel composting is more expensive because it typically involves a dedicated building, aeration and material conveyance equipment, and odor control facilities. Given the range of disposal costs associated with land application ($132 to $217 per dry ton), a facility which moves from Class B to Class A land application via composting will increase biosolids disposal costs on a dollar per dry ton basis by a factor of two or more.

Conventional Class A treatment technologies strive to produce a product that the general public would find esthetically acceptable for home use. At least two Pennsylvania WWTPs are producing an agricultural-grade Class A biosolids product, specifically intended for bulk land application by growers. This approach involves alkaline stabilization (using conventional lime post-treatment equipment), curing, and microbiological testing of batches for compliance with Class A pathogen reduction requirements. Due to the higher level of pathogen treatment (relative to Class B biosolids), agricultural grade Class A biosolids can be managed similar to livestock manures, thus regulatory requirements for spreading are reduced. A facility that is already using alkaline stabilization and land applying a Class B biosolids product, could potentially convert to an ag-grade Class A management scenario with little additional cost. While microbiological testing for Class A pathogen standards would most assuredly increase, regulatory requirements and associated costs for qualifying land application sites are much reduced and the addition of new farms to an existing land application program is easily accomplished. Ag-grade Class A treatment appears to be a promising alternative for achieving advanced pathogen reduction, keeping processing costs in check, and reducing the regulatory burden WWTP operators perceive with conventional Class B land application beneficial use.

FACTORS DETERMINING CURRENT PRACTICES

Survey respondents ranked the following as important factors in the selection of a particular biosolids management option: cost, regulatory requirements, reliability, liability, flexibility, and public acceptance. The prominence of cost is not surprising; municipalities must operate within budget constraints and carefully allocate scarce financial resources. What is somewhat surprising is the fact that landfilling, generally more expensive than land application, is by far the predominant choice for biosolids disposal in the state. Therefore, although ranked as the most important factor, cost minimization is clearly not the sole criterion influencing the existing distribution of biosolids disposal practices in the state.

Regulatory requirements were also ranked highly, and several of the surveys contained comments about the regulatory "hurdles" associated with land application of biosolids. Somewhat surprising was the relative unimportance of public acceptance. This may reflect the fact that most facilities landfill, and although there is typically stiff resistance to siting of new landfills, the specific practice of landfill disposal of biosolids generally does not meet with public resistance. Thus plant managers that landfill simply do not think about public acceptance as being a significant issue relative to WWTP solids. If these same individuals employed land application, it is possible that the issue would be ranked higher.

LOOKING FORWARD

Despite its conceptual appeal and expressed state and federal support, biosolids reuse faces significant logistical challenges, regulatory hurdles, and public resistance. Odor management concerns may be a deciding factor in the selection of biosolids treatment and beneficial use options given the demographic shift to lower density, rural communities where agricultural operations are located. There is also a vocal anti-sludge lobby linking serious adverse environmental impacts and deaths to biosolids land application (Snyder, 2005) and encouraging local ordinances that ban the practice.

Small WWTPs in rural communities may find it increasingly difficult to initiate and sustain beneficial reuse programs. Facilities that continue to recycle biosolids via land application may likely outsource their programs through companies that provide contractual land application services. Even large municipalities may find it expedient to transfer the responsibility for biosolids reuse to contractors. Both Philadelphia and Pittsburgh are pursuing Class A processing of their biosolids, although this does not necessarily imply that these major municipalities will continue beneficial reuse programs. Even now, a significant portion of the biosolids from these cities is land-applied out of state so that much of the benefit is realized outside the commonwealth.

Imposition of phosphorus-based nutrient management to biosolids, in conjunction with Pennsylvania's Chesapeake Bay Tributary Strategy, may force some municipalities to abandon land application programs. Where reductions of effluent nitrogen and phosphorus in wastewater result in elevated concentrations in biosolids (particularly for phosphorus), municipalities may require more land to recycle biosolids at the agronomic rate. Moreover, with the imposition of phosphorus-based nutrient management for biosolids, some existing application sites will not be suitable for land application under the Pennsylvania phosphorus index. The net effect of these changes will be to force some municipalities currently practicing beneficial reuse to landfill their biosolids.

More municipalities may install dryers to condition their biosolids. The primary purpose is to reduce water content and, in turn, handling and transportation costs. However, sludge dryers can be used to produce Class A biosolids, which reduces the regulatory requirements for land-based recycling. Dried biosolids are also less offensive to the public. The key advantage of drying is that it substantially reduces the transportation cost, whether the off-site destination is a landfill or land application site.

The number of facilities incinerating biosolids may remain stable unless the cost of landfilling becomes prohibitively expensive. Given the tremendous capital cost for constructing incinerators and associated air pollution control equipment, the number of biosolids incinerators is not likely to grow in the near future. The amount of biosolids disposed by incineration could increase if existing incinerators were fed wastewater solids from treatment plants in surrounding communities. Thus short-term growth in incineration may likely occur on a contractual basis where WWTP solids are trucked to incinerators from other communities. Because the currently operating incinerators are few and primarily located in urban counties near the state borders, the hauling costs may make this prohibitively expensive for many rural municipalities.

Whether the increase in landfilling cost in the eastern part of Pennsylvania (Garvey, 2005) will lead to more land application programs is not known. If the land application is carried out by a contractor, a municipality could easily move to land application. On the other hand, if a municipality plans to carry out its own land application program, significant time and resources are needed to switch from landfilling to land application.

POLICY CONSIDERATIONS

Policy considerations are based on several core principles. First, biosolids management options must be sustainable for small communities and must promote the welfare of rural residents. Practices must also simultaneously address the dual objectives of cost effectiveness and environmental protection. There are no feasible biosolids management options that are environmentally benign in all respects. Finally, in concert with state priorities (McGinty, 2004), emphasis should be placed on beneficial use and recycling rather than disposal.

Ensure continued availability of landfilling for biosolids management with the ultimate objective of nutrient reuse and energy recovery

Landfill disposal of biosolids should continue to be available to rural communities. Seventy-seven percent of the small facilities (defined as those with flows of less than 1 million gallons per day) practice landfilling. The DEP initiative to limit nutrient discharges for all WWTPs in the Chesapeake Bay watershed will tend to promote more landfilling of biosolids by small municipalities. Higher phosphorus content of the biosolids will mean that some existing land application sites will not be qualified for nitrogen-based nutrient management, according to the Pennsylvania phosphorus index.

A moratorium on biosolids landfilling would have an immediate and devastating impact on small communities because it is difficult and expensive to switch to other disposal options. Regulatory agency variances on satisfying the stabilization and percent solids requirements should be continued since many small communities cannot meet these requirements without significant capital improvements. However, conditions under which a landfill disposal variance is permissible must be clearly articulated. At the time of the study, there did not appear to be a specific set of standards for such variances.

However, policies should encourage beneficial reuse technologies such as land application, landfilling with biogas recovery, or use of biosolids to amend final cover material at landfills. Unless methane is recovered from landfills, biosolids decomposition results in a net elevation of atmospheric carbon dioxide levels (Brown and Leonard, 2004).

Agricultural use should continue to be promoted as a beneficial reuse option

Land application of biosolids should be continued because of the numerous benefits to the farming community. Farmers are involved in such programs because of the agronomic benefits [fertilizer nutrients, organic matter, and lime (for lime-treated biosolids)], tillage, and assistance with conservation and nutrient management planning. The economic benefit of biosolids to participating farmers in one program was calculated to be $95 per acre, or about $20 per dry ton of biosolids (NBP, 2004). With anhydrous ammonia fertilizer prices at an all-time high (NRCS, 2005), there is an increasing incentive for farmers to accept organic nitrogen sources.

The public concern over pathogens in land-applied biosolids foreshadows a future issue with significant policy implications. Current state regulations establish two categories of biosolids: exceptional quality and non-exceptional quality. To qualify as an exceptional quality material, biosolids must meet certain pollutant concentration limits, pathogen reduction standards (Class A versus Class B), and vector attraction reduction standards. Most biosolids in Pennsylvania are classified as non-exceptional quality because the more stringent, and expensive to achieve, Class A pathogen standards are not met. Of the 283 survey respondents, less than 20 provided credible evidence that some portion of their biosolids meet Class A standards.

The key issue is whether the significant additional cost of Class A processing provides measurable and commensurate protection of public health. Land application of Class B materials should be continued. In July 2004, the California State Water Resources Board voted to allow continued application of Class B biosolids in California (National Biosolids Partnership, 2004). The resolution indicated that “having options available is necessary in order to enable POTWs to effectively manage their biosolids at a realistic cost. Adoption of the Class A Only Alternative would create an additional economic burden for POTWs for negligible advantages in health and safety protections.” This is particularly important for rural communities because of the significant incremental unit cost associated with creating a Class A product from a facility currently producing Class B material.

Policies should promote, rather than mandate, processes that produce Class A (exceptional quality) products in small communities. There is a need to promote low cost technology processes for small WWTPs. Small-scale composting processes should be encouraged to allow small communities to gain the economic benefit of sale or use of compost. Alkaline stabilization to produce ag-grade Class A biosolids products specifically intended for bulk land application by growers, offers the opportunity for advanced pathogen reduction, while keeping processing costs in check, and reducing the regulatory burden that many WWTP operators perceive with conventional Class B land application beneficial use. Long-term air-drying is

another low-cost method that can achieve Class A standards. Reed beds are ideal for small WWTP (less than two million gallons per day) and have the potential to result in material meeting Class A standards.

DEP should review regulations to reduce the technical and administrative requirements associated with beneficial reuse. Numerous survey comments indicated that high permitting costs and inflexibility on the part of state regulators were disincentives to biosolids reuse through land application.

Storage policies should be modified to allow pre-positioning of biosolids to take advantage of short-term "windows" when spreading is possible. Moving material is the bottleneck in land application. When farmers indicate a need for biosolids in crop production, it is often not feasible to deliver the biosolids to the fields in a timely manner.

Chemical analysis is sometimes a problem for WWTPs in rural communities. To reduce the regulatory cost on small POTWs, certain test parameters could be waived (e.g., PCBs) if analysis history indicates that the constituent has never exceeded regulatory limits. The PCB analysis requirement in Pennsylvania is above and beyond the Part 503 federal regulations. This approach would be similar to the EPA Pretreatment Streamlining Rule (2005).

Policies should encourage biosolids use in reclamation of degraded lands

Pennsylvania alone has 250,000 acres of land that can only support limited vegetation due to past and existing mining and industrial activities. These degraded lands adversely impact water quality, aesthetic quality, wildlife habitat and land values in rural communities. The use of biosolids to remediate disturbed lands has the triple benefit of terrestrial carbon sequestration, residual utilization, and land reclamation. Historically, Pennsylvania has been a leader in the establishment of regulatory policies for biosolids management under the Solid Waste Management Act. Reclamation of Pennsylvania mine lands with biosolids since the 1970s remains the preeminent guidance nationwide for this practice. Land application was first regulated in 1977 under Title 25, Chapter 75 of the Pennsylvania Code.

Biosolids use in reclamation allows a protective vegetative cover to be quickly established and the practice does not pose any significant threat to human or animal health (Epstein, 2003b). Many of the health and aesthetic concerns associated with agricultural application are less important in reclamation activities. The use of biosolids for reclaiming disturbed lands should be continued and encouraged.

For reclamation of drastically disturbed sites, state regulations should allow application rates to exceed 60 dry tons per acre (as allowed in other states). The predictable short-term loss of nitrate to groundwater is more than offset by the positive effects of rebuilding soils, rapid establishment of vegetation, and returning the site to productive land uses.

Policies should promote public/private partnerships to accomplish reclamation activities. Companies that invest or fund reclamation projects can bank carbon credits and apply them to offset their own emissions. Municipalities could gain carbon credits that could be sold to industries.

Policies should encourage use of biosolids products, on state contracted projects where appropriate. For example, widespread use of biosolids products for establishing and maintaining vegetation in state roadside and median strip plantings (turf, flowers, shrubs, etc.) would be an excellent beneficial use outlet. Use of biosolids for reclamation of burn areas in state forests is another excellent use. In 1990, the Bureau of Forestry demonstrated the benefits of biosolids in re-vegetating burn areas, but strong public resistance to the practice has resulted in a policy against biosolids use in state forests (Kugel, 2006). Such biosolids-unfriendly policies should be revisited and made consistent with Pennsylvania's overarching policy to promote beneficial use and recycling.

Brownfields offer another opportunity for biosolids recycling. Promoting brownfield development and community revitalization is a priority for the current DEP administration (McGinty, 2004). Biosolids have been shown to be effective in establishing vegetation at abandoned industrial sites (Brown et al., 2003). As with reclamation of mined sites, state guidelines should allow application rates to exceed 60 dry tons per acre when appropriate.

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