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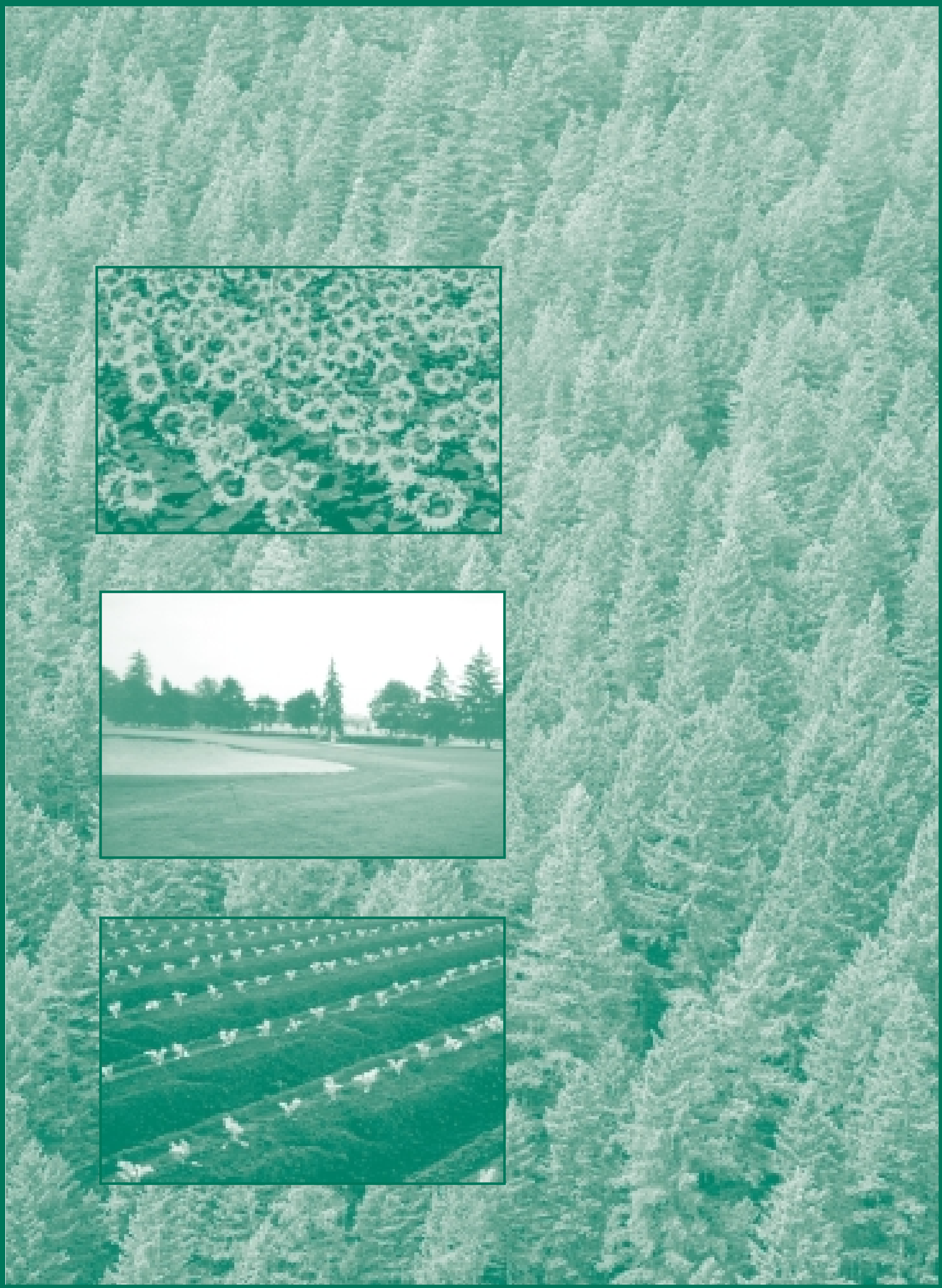
Biosolids Generation, Use, and Disposal in The United States



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Biosolids Generation, Use, and Disposal in the United States

U.S. Environmental Protection Agency
Municipal and Industrial Solid Waste Division
Office of Solid Waste
EPA530-R-99-009

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Executive Summary

The purpose of this report is to broaden the U.S. Environmental Protection Agency's (EPA) series of solid waste studies by quantifying the amount of biosolids managed by municipal solid waste (MSW) facilities. Biosolids are the byproduct of municipal wastewater treatment and also are known as sewage sludge. This report focuses on biosolids generated by publicly owned treatment works (POTWs) and the subsequent management practices used by POTWs for treating and then recycling or disposing of biosolids. The quantity of biosolids processed by POTWs and the treatment methods they select are likely to affect MSW decision-makers regarding their involvement in biosolids management.

EPA hopes to support MSW operators and state and local solid waste decision-makers in developing coordinated biosolids management programs with local POTWs and other generators to encourage the cost-effective, beneficial use of biosolids. In beneficial use, biosolids are used for their soil-conditioning and nutrient-containing properties. This report also examines the advantages to MSW operators of using biosolids in composting operations for land application and sale to the public. The key areas discussed in this report regarding the beneficial use or the disposal of biosolids, particularly at MSW facilities, are detailed below:

- **The use or disposal of biosolids**

  — The use or disposal of biosolids begins with wastewater treatment. The type and level of wastewater treatment has an effect on the type, quantity, and quality of biosolids generated. Pretreatment of wastewater by industry can improve biosolids quality considerably.

  — Biosolids treatment is inherent in the proper use of wastewater solids. Various stabilization processes control odor, pathogens (e.g., disease-causing bacteria and viruses), biodegradable toxins (e.g., hydrocarbons), and vectors (e.g., rodents and flies) and can bind heavy metals. Composting is a highly effective way of stabilizing and reducing pathogens in biosolids, resulting in a valuable soil conditioning product that often has many useful properties (e.g., slower and steadier nutrient availability unmatched by conventional chemical fertilizers). Dewatering is necessary for landfilling and incineration of biosolids and can be a critical step in preparing biosolids for composting.

— Biosolids management practices primarily involve land application, which can include the use of compost or other highly treated biosolids and other beneficial uses (e.g., landfill cover). Other biosolids management options include landfilling and other forms of surface disposal and incineration.

- **Quantities of biosolids generated, used, and disposed of between 1998 and 2010**

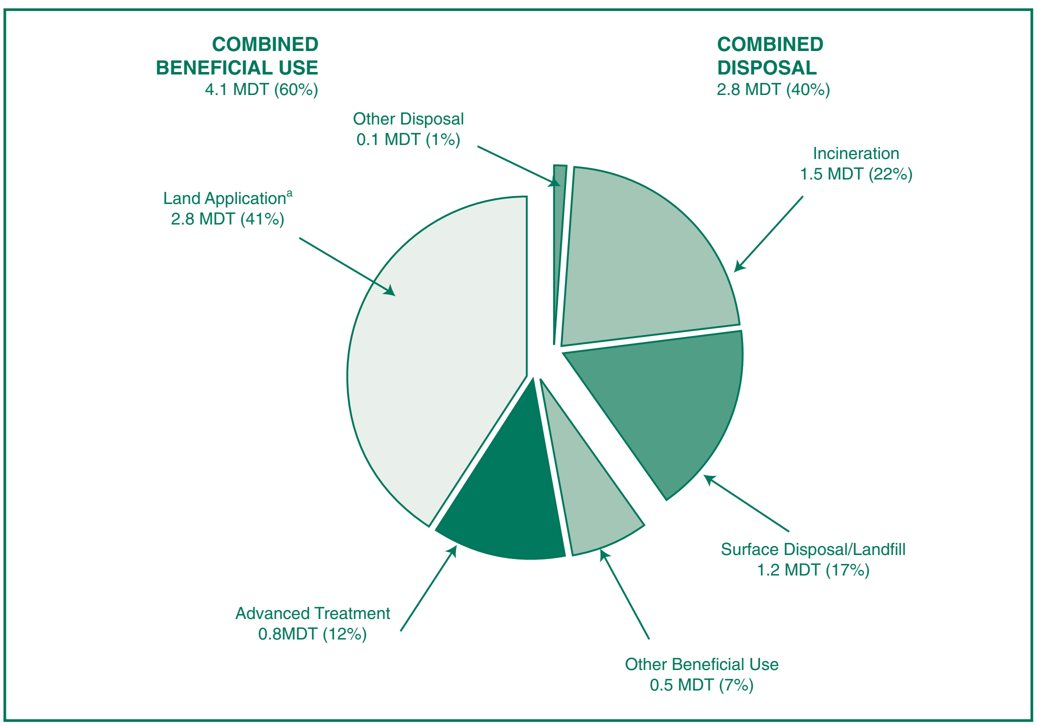
— This report estimates that approximately 6.9 million tons of biosolids were generated in 1998, of which about 60 percent were used beneficially (e.g., land applied, composted, used as landfill cover) and 40 percent disposed of (i.e., discarded with no attempt to recover nutrients or other valuable properties). This report further estimates that at least 20 percent of biosolids were managed by MSW facilities through either landfilling (17 percent) or as landfill cover (3 percent). An estimated additional 6 percent were managed by MSW facilities in composting programs. "MSW facility" defined here includes any commercial, noncommercial, or municipal entity that composts organic MSW (e.g., yard trimmings) with biosolids. Thus, about a quarter of all biosolids have been managed by MSW facilities, mostly by MSW landfill operators (see Figure ES-1).

— We expect that the use of biosolids will increase in the future due to the benefits from recycling, cost considerations, and public perception issues associated with disposal. In 2000, we estimate that 7.1 million tons of biosolids will be generated for use or disposal, growing to 7.6 million tons in 2005 and to 8.2 million tons in 2010. We anticipate that the percentage of biosolids used (rather than disposed of) will grow from 63 percent in 2000 to 66 percent in 2005 and to 70 percent in 2010. A trend away from disposal and toward use would result in a decline in biosolids disposed of in MSW landfills and an increase in the use of biosolids as landfill cover and in composting programs at MSW facilities. In 2000, we estimate that at least 14 percent of biosolids will be landfilled and 3 percent used as landfill cover. An estimated additional 6 percent might be used in composting programs, for a total of at least 17 percent to a possible 23 percent of all biosolids managed by MSW facilities. We expect that changes will occur in 2005 due to increasing reuse of biosolids and a corresponding decrease in landfilling, primarily because of cost and siting considerations. An estimated 13 percent will be landfilled, 3 percent will be used as landfill cover, and 6.5 percent will be composted at MSW facilities, for a total of at least 16 percent to possibly 22 percent of biosolids being managed by MSW facilities by 2005. In 2010, we estimate that 10 percent might be landfilled, 3 percent used as landfill cover, and possibly 7 percent used in composting programs, for a total of at least 13 percent to possibly 20 percent of biosolids managed by MSW facilities (as defined above).

• Concerns about beneficial use and ways to address them

— The beneficial use of biosolids is hindered by public opposition in some areas of the country. The public acceptance issues involve concerns about pollutants in the biosolids, risk of disease, and nuisance issues such as odors. When properly treated and managed in accordance with existing regulations and standards, biosolids are safe for the environment and human health. Furthermore, over time, as industrial pretreatment of wastewater has advanced, the quality of biosolids has continued to improve. Public acceptance concerns can be effectively addressed through a combination of approaches, including careful assessment of public attitudes, modifications to biosolids management programs, aggressive outreach and education, and strong marketing of biosolids products. These approaches are successfully employed by a number of biosolids managers (as presented in the case studies in Section 5.3), resulting in highly effective programs that emphasize cost-effective beneficial use of biosolids. In addition, a new Environmental Management System for biosolids management is being developed, with the support of Congress, by the National Biosolids Partnership program. Voluntary membership in the National Biosolids Partnership program includes the public, generators, land appliers, farmers, academics, federal, state, and local governments, and other interested parties.

Figure ES-1
Estimates of Biosolids Use and Disposal (1998)



MDT (1998) = millions of dry tons
Source: See Appendix A.3.
[a]Without further processing or stabilization such as composting.

Section One

Introduction

Biosolids (historically known as sewage sludge) are the solid organic matter produced from private or community wastewater treatment processes that can be beneficially used, especially as a soil amendment. The amount of biosolids generated and the use or disposal of biosolids, as discussed in this report, are of interest to municipal solid waste (MSW) facility operators and others (e.g., farmers, foresters, land reclaimers, landscapers) for several reasons, including:

- Disposal of biosolids commonly occurs in MSW landfills
- Ash from biosolids incineration might be disposed of in MSW landfills
- Biosolids can be composted (recycled) with other organic MSW materials
- Biosolids can be used as a soil amendment and fertilizer
- Biosolids can be used as daily cover or part of a final landfill cover

This report discusses the amount of biosolids generated in the United States and their subsequent use or disposal. Section Two summarizes the various treatment, use, and disposal practices for biosolids and includes brief references to regulatory requirements influencing these practices. Section Three provides actual estimates of the amount of biosolids generated, recovered, and disposed of in the United States. Section Four discusses current and possible future trends in the generation, use, and disposal of biosolids through 2010. Section Five discusses beneficial uses of biosolids, addresses concerns about beneficial use, and presents several case studies that illustrate a variety of successful biosolids management programs. The Appendix provides the full methodology and detailed results of the data analyses summarized in Sections Three and Four.

1.1 How This Report Can Be Used

This report contains information on biosolids treatment and management that may be useful to MSW managers who are considering the impact of biosolids on their operations, as well as for other varied users of biosolids. MSW managers can use the generation, use, and disposal figures in this report, for example, to gain a better perspective of the various management options available for biosolids and what the current trends are in the use and disposal of biosolids. MSW managers can also use this report to explore what trends may affect future biosolids management practices over the next 15 years, including the potential markets for composted biosolids. This report also may help clarify the relationship between MSW facility operators and POTW operators and encourage them to work cooperatively. By showing how solid wastes, such as yard trimmings, and biosolids can be managed together in a composting operation, for example, this report might help various municipal groups, such as solid waste and wastewater treatment departments, deal more efficiently and cooperatively with recycling and waste handling issues. Federal, state, and local solid waste decision-makers can use this report to help determine the amounts of biosolids potentially available for beneficial use projects and facilitate planning for future use and disposal operations.

The data estimates made in this report target the quantities of biosolids that are likely to be generated by POTWs whose management practices ultimately affect the quality of resulting biosolids and, therefore, MSW facilities' management options. For that reason, this report does not include information on domestic septage that is not treated at POTWs. Domestic septage is the liquid or solid material removed from septic tanks, cesspools, portable toilets, Type III marine sanitary devices, or similar systems. This report also does not quantify the amount of biosolids incinerator ash generated and disposed of, although up to 22 percent of total biosolids generated in 1998 were incinerated. Biosolids incineration as a disposal practice, however, is discussed in this report.

1.2 Sources of Information

To estimate biosolids generation, use, and disposal and to prepare this report, a number of information sources were used. The 1988 National Sewage Sludge Survey (NSSS) surveyed 479 POTWs in 1988 and provided a statistically valid estimate of the amounts of biosolids used or disposed of by POTWs using secondary or tertiary treatment in that year (U.S. EPA, 1993a). EPA's Needs Survey (1986 through 1996 data) also was used in this report and assesses the number of wastewater treatment facilities in operation, their existing and projected wastewater flow, and the number of people they serve. In addition, the results of the following recent studies and surveys were used: a 1995 inventory conducted by the Water Environment Federation (WEF) and the Association of Metropolitan Sewerage Agencies (AMSA) on biosolids generation, beneficial use, and disposal (WEF, 1997); a 1996 survey of state regulators (Bastian, 1997); and 1991, 1997, and 1998 surveys of state regulators (*BioCycle*, 1991, 1997, and 1998). In the near future, however, data on biosolids quality and management will be more readily available through EPA's Biosolids Data Management System, which is a data program that allows for electronic reporting (and access of data) among treatment facilities, states, and EPA.

These sources and the information used are discussed in more detail in the Appendix. Additional sources of information are cited as referenced; full citations can be found in the references section at the end of this report.

Section Two

Background

The Clean Water Act requires that communities treat their wastewater to return this resource safely to the environment. When wastewater is treated, the process produces a semisolid, nutrient-rich byproduct known as biosolids. When treated and processed properly, biosolids can be recycled and applied to crop land to improve soil quality and productivity because of the nutrients and organic matter that they contain. Historically called sewage sludge, biosolids is the term now used to emphasize the beneficial nature of this recyclable material.

Biosolids often contain approximately 93 to 99 percent water, as well as solids and dissolved substances present in the wastewater or added during wastewater or biosolids treatment processes. The quantity of municipal biosolids produced annually in the United States has increased dramatically since 1972, from roughly 4.6 million dry tons in 1972 (Bastian, 1997) to 6.9 million dry tons in 1998. This is a 50 percent increase from 1972, when the Clean Water Act first imposed minimum treatment requirements for municipal wastewater, and is greater than the 29 percent increase in U.S. population from 1972 to 1998 (Council of Economic Advisors, 1999).

Treatment works treat both wastewater as well as the resulting biosolids, often using different technologies designed specifically for each treatment process. This section, therefore, divides the discussion of treatment into wastewater treatment and biosolids treatment. The influence of wastewater treatment on biosolids generation is addressed first, followed by a discussion of biosolids treatment. The different types of biosolids use and disposal practices are then discussed, including practices that might involve MSW facilities. Additionally, the regulatory requirements found in The Standards for the Use or Disposal of Sewage Sludge (Title 40 of the *Code of Federal Regulations* [CFR], Part 503), which was published in the *Federal Register* in 1993, are discussed and will be referred to in this document as “the Part 503 Biosolids Rule” or “Part 503.” This rule establishes the regulations limiting the pollutants and pathogens in biosolids. Also discussed are the municipal solid waste landfill regulations, published in 1991 under Title 40 CFR Part 258, as they apply to the disposal of biosolids in MSW landfills. Discussion of landfill regulations in this document will be referred to as “the Part 258 Landfill Rule.”

2.1 Wastewater Treatment

Domestic, commercial, and industrial wastewater are collected through an extensive network of sewers and transported to wastewater treatment plants (usually POTWs).[1] Prior to the release of wastewater into the municipal sewer network, most industrial plants must pretreat their wastewater to remove certain contaminants (including metals, such as copper, lead, cadmium, and chromium, and other pollutants such as chlorinated hydrocarbons). Over the past 20 years, industrial pretreatment and pollution prevention programs have substantially reduced levels of metals and other pollutants going into POTWs, resulting in noticeable improvements in biosolids quality (Walker, 1998). At the POTW, before it is discharged into the environment, wastewater undergoes preliminary, primary, secondary, and, in some cases, tertiary treatment (see Table 2-1). The quantity and characteristics of the biosolids generated at a POTW depend on the composition of the wastewater, the type of wastewater treatment used, and the type of subsequent treatment applied to the biosolids. Even within an individual plant, the characteristics of the biosolids produced can change annually, seasonally, or even daily because of variations in the incoming wastewater composition and variations in treatment processes.

Generally, higher degrees of wastewater treatment can increase the total volume of biosolids generated. Higher levels of treatment also can increase the concentrations of contaminants in biosolids, because many of the constituents removed from the wastewater end up in the biosolids. Furthermore, wastewater processes that involve the addition of chemicals to precipitate the solids (such as ferric chloride, alum, lime, or polymers) can result in increased concentrations of these chemicals in the biosolids. Other, indirect effects also can occur, such as when alum (as aluminum hydroxide) adsorbs phosphorus or causes trace metals (e.g., cadmium) to precipitate out of the wastewater and into the biosolids. Industrial pretreatment regulations for wastewater, required by federal and state agencies, as well as pollution prevention programs can reduce levels of metals and other pollutants in the wastewater treated at POTWs and in the subsequent biosolids produced. Thus, the type of wastewater treatment or pretreatment used affects the characteristics of biosolids, which in turn can affect the types of biosolids treatment chosen. The marked improvements in biosolids quality resulting from pretreatment and pollution prevention programs, for example, can encourage POTWs to process their solids further, such as by composting them. When biosolids achieve the low levels of pollutants that make the widest distribution of biosolids products possible, processes such as composting become more attractive.

[1] Although the focus of this report is on biosolids generated by POTWs, quantities of biosolids generated by privately and federally owned treatment works are included in estimates presented in Sections Three and Four. Operations at these treatment works, although smaller than those at many POTWs, are similar to POTWs.

Table 2-1
Types of Wastewater Treatment and Resulting Types of Biosolids

Wastewater Treatment Level	Types of Biosolids Produced
Screening and Grit Removal	
Wastewater screening removes coarse solids that can interfere with mechanical equipment. Grit removal separates heavy, inorganic, sandlike solids that would settle in channels and interfere with treatment processes.	Screenings and grit are handled as a solid waste and nearly always landfilled. This material is excluded from the definition of biosolids and from the 40 CFR Part 503 regulation governing the use or disposal of biosolids.
Primary Wastewater Treatment	
Usually involves gravity sedimentation of screened, degritted wastewater to remove suspended solids prior to secondary treatment.	Biosolids produced by primary wastewater treatment usually contain 3 to 7 percent solids; generally their water content can be easily reduced by thickening or dewatering.
Secondary Wastewater Treatment	
Generally relies on a biological treatment process (e.g., suspended growth or fixed growth systems), in which microorganisms are used to reduce biochemical oxygen demand and remove suspended solids. Secondary treatment is the minimum treatment level required for POTWs under the Clean Water Act.	Biosolids produced by secondary wastewater treatment usually have a low solids content (0.5 to 2 percent) and are more difficult to thicken and dewater than primary biosolids.
Tertiary (Advanced) Wastewater Treatment	
Used at POTWs that require higher effluent quality than that produced with secondary treatment. Common types of tertiary treatment include biological and chemical precipitation and processes to remove nitrogen and phosphorus.	Lime, polymers, iron, or aluminum salts used in tertiary wastewater treatment produce biosolids with varying water-absorbing characteristics. Also, high-level lime precipitation produces alkaline biosolids.

2.2 Biosolids Treatment

Most biosolids undergo additional treatment on site before they are used or disposed of to meet regulatory requirements that protect public health and the environment, facilitate handling, and reduce costs. Biosolids characteristics can determine a municipality's choice of use or disposal methods. Only biosolids that meet certain regulatory requirements for pathogens, vector attraction reduction, and metal content (discussed in Section 2.3.1), for example, can be land applied or used as compost. Even those biosolids that are disposed of rather than land applied must meet regulatory requirements (see Sections 2.3.2 and 2.3.3). Also, with regard to handling and cost, the water content of biosolids can affect many aspects of biosolids management, such as transportation and the size of treatment and use or disposal operations. Some biosolids treatment processes reduce the volume or mass of the biosolids (such as biosolids digestion processes), while others increase biosolids mass (for example, when lime is added to control pathogens.) The two most common types of biosolids treatment processes are stabilization and dewatering.[2]

Stabilization refers to a number of processes that reduce pathogen levels, odor, and volatile solids content. Biosolids must be stabilized to some extent before most types of use or disposal. Major methods of stabilization include alkali (lime) stabilization, anaerobic digestion (digestion of organics by microorganisms in the absence of oxygen), aerobic digestion (digestion of organics by microorganisms in the presence of oxygen), composting, and/or heat drying (described in more detail in Section 2.2.1).

Dewatering removes excess water from biosolids and generally must be performed before biosolids are composted, landfilled, dried (e.g., pelletized or heat dried), or incinerated. A number of dewatering processes can be used, including air drying, vacuum filters, plate-and-frame filters, centrifuges, and belt filter presses (discussed in Section 2.2.2).

2.2.1 Stabilization Processes

Alkaline Stabilization

The improved structural characteristics of stabilized biosolids (compared to dewatered biosolids cake without lime stabilization) generally reduce pathogens and odors, allow for more efficient handling operations, and provide a source of lime to help neutralize acid soils. While lime is most commonly used, other alkaline materials, such as cement kiln dust, lime kiln dust, Portland cement, and fly ash, have also been used for biosolids stabilization.

[2] Most of the information discussed in Sections 2.2.1 and 2.2.2 has been taken from the *Regulatory Impact Analysis of the Part 503 Regulations* (U.S. EPA, 1993a), *Process Design Manual on Land Application of Sewage Sludge* (U.S. EPA, 1995a), *A Plain English Guide to the Part 503 Biosolids Rule* (U.S. EPA, 1994a), and *Use and Disposal of Municipal Wastewater Sludge* (U.S. EPA, 1984).

Historically, alkaline stabilization has been implemented using either quicklime (CaO) or hydrated lime ($CA[OH]_2$), which is added to either liquid biosolids before dewatering or dewatered biosolids in a contained mechanical mixer. Traditional lime stabilization processes are capable of producing biosolids meeting the minimum pathogen and vector attraction reduction requirements found in the 40 CFR Part 503 rules governing land application of biosolids; sufficient lime is added so that the pH of the biosolids/lime mixture is raised to 12.0 or above for a period of 2 hours. The elevated pH helps to reduce biological action and odors.

In recent years, a number of advanced alkaline stabilization technologies have emerged, some of which use other chemical additives to replace the lime (in part or fully). Many of the newer technologies use similar biosolids handling and mixing equipment as traditional lime stabilization (although some use special equipment), but the precise chemical formulas of the stabilization additives and/or the processing steps used are generally proprietary. Thus, many of these technologies are available only to POTWs as procurements from private firms.

The most common modifications used in these newer technologies include the addition of other chemicals, a higher chemical dose, and/or supplemental drying, which: 1) increase solids content and granularity; 2) reduce mobility of heavy metals; 3) increase the agricultural lime value; 4) achieve a higher degree of pathogen reduction, including the production of a biosolids product with pathogens below detectable levels; and/or 5) achieve long-term stability of the product to allow for storage with minimum potential for odor production or regrowth of pathogens. Potential markets for advanced alkaline-stabilized biosolids products include agricultural, slope stabilization, structural fill, and MSW landfill cover operations.

Anaerobic Digestion

Anaerobic digestion involves biologically stabilizing biosolids in a closed tank to reduce the organic content, mass, odor (and the potential to generate odor), and pathogen content of biosolids. In this process, microorganisms consume a part of the organic portion of the biosolids. Anaerobic bacteria that thrive in the oxygen-free environment convert organic solids to carbon dioxide, methane (which can be recovered and used for energy), and ammonia. Anaerobic digestion is one of the most widely used biosolids stabilization practices, especially in larger treatment works, partly because of its methane recovery potential. Anaerobic digestion is typically operated at about 35° C (95° F), but also can be operated at higher temperatures (greater than 55° C [131° F]) to further reduce solids and pathogen content of the stabilized biosolids.

Aerobic Digestion

Aerobic digestion involves biologically stabilizing biosolids in an open or closed vessel or lagoon using aerobic bacteria to convert the organic solids content to carbon dioxide, water, and nitrogen. Pathogens and odors (and the potential to generate odors) are reduced in the process. Aerobic digestion is commonly used by smaller POTWs and often is accomplished using wastewater treatment lagoons containing aeration equipment. The high-temperature operation (i.e., higher than 55° C [131° F]) of aerobic digestion is becoming more popular because it can produce biosolids with lower pathogen levels and higher solids content.

Composting

Composting is the decomposition of organic matter by microorganisms in an environment that controls the size and porosity of the pile, thereby facilitating an increase in temperature (typically to about 55° to 60° C [131° to 140° F]) to destroy most pathogens. The moisture and oxygen levels of this process are also controlled to reduce the potential for processing odors. During the process, biosolids are degraded to a humus-like material with excellent soil conditioning properties at a pH range of 6.5 to 8, which is conducive to growing healthy plants and reducing the mobility of metals. Composting involves mixing dewatered biosolids with a bulking agent (such as wood chips, municipal yard trimmings, bark, rice hulls, straw, or previously composted material) and allowing the biosolids mixture to decompose aerobically (in the presence of oxygen) for a period of time. The biosolids mass is initially increased due to the addition of the bulking agent. The bulking agent is used to lower the moisture content of the biosolids mixture, increase porosity, and add a source of carbon. Depending on the method used, the biosolids compost can be ready in about 3 to 4 weeks of active composting followed by about one month of less-active composting (curing).

Three different composting processes are typically used: windrow composting, aerated static piles, and in-vessel composting. In *windrow composting*, the biosolids and bulking agent mixture are formed into long, open-air piles. The piles are turned frequently to introduce oxygen into the pile, ensure that adequate moisture is present throughout the pile, and ensure that all parts of the pile are subjected to temperatures of 55° C (131° F) for destruction of pathogens. *Aerated static piles* (or windrows) are rectangular piles supplied with oxygen via blowers connected to perforated pipes or grates running under the piles. In-vessel composting takes place in a completely enclosed container where temperature and oxygen levels can be closely monitored and controlled. In-vessel composting also helps contain process and building air so that it can be captured and treated for odors.

Various odor control measures, such as frequent turnings, are used in conjunction with most composting operations (see Section Five). Frequent turnings help reduce odor-producing anaerobic pockets in the composting biosolids by introducing oxygen and remixing pile ingredients. This approach, however, might not work well for large operations near residential areas because the turnings themselves (while adding more oxygen to the process) generate more odors initially. In these cases, timing the turnings to occur when conditions are ideal (such as when climate conditions are most advantageous) is used to minimize odors as well as collecting and scrubbing the off-gasses chemically or biologically (through packed towers, mist towers, or constructed biofilters).

Biosolids composting might interest MSW facility operators because biosolids can be composted in combination with various organic components of MSW such as yard trimmings (e.g., leaves, grass clippings, brush), paper, and chipped wood debris. The benefits of composting (see Table 2-2) include diverting these resources from landfills while producing a high-quality soil amendment. If biosolids are included as part of the compost, the processing and product are subject to the 40 CFR Part 503 Biosolids Rule. Furthermore, if the finished compost product meets 40 CFR Part 503 Biosolids Rule Class A specifications for the highest level of pathogen and vector control (as described in Section 2.3.1) and specific metals limits, the compost product can be widely used, like any other fertilizer or soil-conditioning product. MSW operators who compost can simply meet these Part 503 Biosolids Rule requirements for Class A pathogen status and vector attraction reduction by using good management practices, careful documentation, and high-quality biosolids (that meet the pollutant concentration limits in Table 3, Section 503.13). Important end uses for biosolids compost include landscaping projects, nursery operations, and applications to parks, lawns, and home gardens. Additionally, biosolid compost is often used for soil blending, landfill cover, application to golf courses, mine reclamation, degradation of toxics, pollution prevention, erosion control, and wetlands restoration. It also is used for agricultural purposes, such as application to citrus crops (*BioCycle*, 1997 and U.S. EPA, 1997a). Composts made from biosolids can also be tailored to remediate contaminated soils (U.S. EPA, 1997a; U.S. EPA 1998a).

Although biosolids compost has less total nitrogen than most other forms of treated biosolids (due to processing and dewatering, dilution of nutrients by bulking material, and loss of ammonia during the composting process), this nitrogen is released more slowly and, thus, is available to plants over a longer period of time, which is more consistent with plant uptake needs. Biosolids compost also is an excellent soil conditioner, and the slow release of nitrogen in compost reduces leaching of nitrogen into the water table—a common problem with other types of soil conditioners and conventional fertilizers. Also, by promoting a healthy soil microflora, compost can help prevent plant diseases. For more information on the composting process, see Section Five, as well as the sources *Composting of Yard Trimmings and Municipal Solid Waste* (U.S. EPA, 1993b), *Compost—New Applications for an Age-Old Technology* (U.S. EPA, 1997a), and *An Analysis of Composting as an Environmental Remediation Technology* (U.S. EPA, 1998a). A number of communities have highly successful, cost-effective composting programs. In 1997, 198 biosolids composting facilities were in operation in the United States (*BioCycle*, 1998). Some of these programs are profiled in Section Five.

Table 2-2
Benefits of Using Compost

Benefit	Description
Soil Enhancement	Compost aerates the soil and improves the soil's water-holding capacity and structure by adding organic materials.
Plant Growth	Compost provides a slowly released, long-term source of nutrients, promotes faster root development, and can reduce plant disease by promoting beneficial microorganisms that reduce plant parasites.
Pollution Prevention	• The soil and plant improvements that composting provides can result in reduced use of fertilizers and pesticides. • When compost is used, fertilizers, metals, organic chemicals, and pesticides are less able to migrate to and contaminate ground water and surface water. • Compost also can help prevent soil erosion by increasing water infiltration. • Composting instead of landfilling reduces methane gas formation in landfills, which can contribute to global warming if not appropriately captured and utilized.

Source: Adapted from Garland, et al., 1995.

Heat Drying and Pelletizing

Heat drying involves using active or passive dryers to remove water from biosolids (solar drying is used in some locations). It is used to destroy pathogens and eliminate most of the water content, which greatly reduces the volume of biosolids. Heat-dried biosolids from secondary treatment processes generally do not have objectionable odors, especially when stored dry, whereas heat-dried primary biosolids can have objectionable odors even when stored dry. Several highly successful products are prepared using this process (e.g., Milorganite®, produced and sold by the city of Milwaukee since the 1920s) (U.S. EPA, 1995a). Heat drying has the advantage of conserving nitrogen but does require fuel for processing. In some cases, the heat-dried biosolids are formed into pellets. These products are very dry and, therefore, can save significantly on transportation costs over compost or other forms of biosolids with higher moisture contents. Thus, heat drying and pelletizing might be processes of choice for urban communities where distances to agricultural land can be substantial. Boston, Massachusetts, and New York City, for example, pelletize and transport their biosolids out of state.

2.2.2 Dewatering

Dewatering decreases biosolids volume by reducing the water content of biosolids and increasing the solids concentration. Dewatering often is a necessary process before treatment or use, such as before composting, heat drying, or biosolids preparation for land application, although liquid biosolids can be land applied using common or specialized application methods (see Section 2.3.1). Dewatering also is necessary for biosolids destined for incineration to prevent damage to boilers and decrease the energy required for biosolids combustion. Additionally, landfilled biosolids are required to be dewatered because disposal of liquids in landfills is prohibited. Dewatering makes handling of the biosolids easier by converting liquid biosolids to a damp cake and reduces transportation costs, although cost savings should be weighed against the cost of dewatering. Dewatering might be undesirable for land application of biosolids in regions where water itself is a valuable agricultural resource.

Prior to dewatering, biosolids are usually conditioned and thickened. In conditioning, chemicals, such as ferric chloride, lime, or polymers, are added to facilitate the separation of solids by aggregating small particles into larger masses or "flocs." In thickening, part of the water bound to biosolids particles is removed to concentrate the solid materials. Gravity thickening is a common practice (Walker, 1998).

Typical dewatering methods include air drying and mechanical systems. *Air drying* involves placing biosolids on a sand bed and allowing them to dry through evaporation and drainage. This process can produce a solids content in primary biosolids of as high as 45 to 90 percent. Air drying systems are relatively simple in terms of operation but require large land areas and relatively long periods of time and, therefore, tend to be used by small POTWs that generate small amounts of biosolids. Larger POTWs rely on mechanical dewatering systems such as *vacuum filters*, plate-and-frame filter presses, centrifuges, and belt filter presses. Vacuum filters, which typically achieve 12- to 22-percent solids content, involve rotating a drum submerged in a vat of biosolids and applying a vacuum from within the drum, drawing water into the drum, and leaving the solids or “filter cake” on the outer drum filter medium. The dewatered biosolids are scraped off the filter. This form of dewatering is now being replaced by belt filter presses, *centrifuges*, and, in some cases, plate-and-frame presses. Centrifuges spin biosolids in a horizontal, cylindrical vessel at high speeds, with the solids concentrating on the outside of the vessel. These solids are then scraped off. Centrifuging can result in a 25- to 35-percent solids content. *Belt filter presses* can achieve 20- to 32-percent solids content. They work by exerting pressure on biosolids placed between two filter belts, which are passed through a series of rollers. The pressure forces water out of the biosolids, and the dried biosolids cake is retained on the filter belt. *Plate-and-frame presses* are the most expensive system to operate and can produce 35- to 45-percent solids content. They work by squeezing the biosolids between two porous plates or diaphragms. The pressure forces water out of the biosolids, and the dried biosolids cake is retained on the plates.

Table 2-3 presents some of the common stabilization technologies and the use or disposal method typically associated with each process.

Table 2-3
Stabilization Technologies and Associated Use or Disposal Methods

Treatment Process	Use or Disposal Method
Aerobic or Anaerobic Treatment (Digestion)	Produces biosolids used as a soil amendment and organic fertilizer on pasture and row crops, forests, and reclamation sites; additional treatment, such as dewatering, also can be performed (see note below).
Alkaline Treatment	Produces biosolids useful for land application and for use as daily landfill cover.
Composting	Produces highly organic, soil-like biosolids with conditioning properties for horticultural, nursery, and landscape uses.
Heat-Drying/Pelletizing	Produces biosolids for fertilizers generally used at a lower rate because of higher cost and higher nitrogen content.

Note: Two or more processes are often used for treating biosolids (e.g., anaerobic digestion with dewatering and composting).
Source: Adapted from U.S. EPA, 1997b.

2.3 Biosolids Use and Disposal Practices

The most common destinations for biosolids include various types of land application sites (after the biosolids have been treated to meet regulatory requirements), landfills, and incinerators.

2.3.1 Land Application and Other Beneficial Use Options for Biosolids

Land application involves the spreading of biosolids on the soil surface or incorporating or injecting biosolids into the soil. Land application has been practiced for decades and continues to be the most common method for using biosolids. Biosolids serve as a soil enrichment and can supplement or replace commercial fertilizers. Nutrients (e.g., nitrogen and phosphorus), micronutrients including essential trace metals (e.g., copper, zinc, molybdenum, boron, calcium, iron, magnesium, and manganese), and organic matter in the biosolids are beneficial for crop production, gardening, forestry, turf growth, landscaping, or other vegetation.

Biosolids generally have lower nutrient contents than commercial fertilizers. Biosolids typically contain 3.2 percent nitrogen, 2.3 percent phosphorus, and 0.3 percent potassium, while commercial fertilizers might contain 5 to 10 percent nitrogen, 10 percent phosphorus, and 5 to 10 percent potassium (Metcalf & Eddy, 1991). Nevertheless, the use of biosolids conditions the soil and reduces or eliminates the need for commercial fertilizers, thereby reducing the impacts of high levels of excess nutrients entering the environment. Furthermore, although biosolids contain metals, so do fertilizers, although data on metals in fertilizers are not comprehensive. States are only now starting to look at regulating metals levels in fertilizers, whereas metals in biosolids have been regulated for years. See Box 1 for a discussion of regulations affecting the land application and other beneficial uses of biosolids.

Biosolids treatment before land application can involve digestion, composting, alkaline treatment, heat treatment, or other methods. Biosolids are treated to different levels, depending on the end use. In many cases, land application of biosolids is less expensive than disposal methods (*Federal Register*, Vol. 54, No. 23, pp. 5476-5902, February 6, 1989). Biosolids composting adds cost, but the resulting compost has a wide variety of uses, and a composting program has the potential to reduce municipal funding normally spent on purchasing soil amendments and/or provide a high-quality compost to many other users. Furthermore, composting offers ease of storage and ease of application because of its semidry product, less odors, and more flexibility in land application due to its high quality.

Some of the uses for biosolids and biosolids composts include their application to various types of land including agricultural lands, forests, mine reclamation sites and other drastically disturbed lands, parks, and golf courses. Composted and treated biosolids are used frequently by landscapers and nurseries and by

Box 1: Regulations Affecting Beneficial Use of Biosolids

Biosolids must meet the requirements specified in the 40 CFR Part 503 Biosolids Rule, “The Standards for the Use or Disposal of Sewage Sludge” before they can be beneficially used. The Part 503 Biosolids Rule land application requirements ensure that any biosolids that are land applied contain pathogens and metals that are below specified levels to protect the health of humans, animals, and plants. Part 503 also requires that the biosolids are applied at an “agronomic rate,” which is the biosolids application rate designed to provide the amount of nitrogen needed by the crop or vegetation and to minimize the amount of nitrogen in the biosolids that passes below the root zone of the crop to the ground water. In addition, Part 503 requires that vector (e.g., flies and rodents) attraction be reduced and includes specific management practices, monitoring frequencies, and recordkeeping and reporting requirements.

More specifically, the Part 503 Biosolids Rule sets metals limits in land applied biosolids for nine metals. Four sets of limits are provided: the ceiling limits for land application, more stringent high-quality pollutant concentration limits, the cumulative loading limits, and the annual limits for bagged products not meeting the high quality pollutant concentration limits. Biosolids that meet pollutant concentration limits can be applied to sites without tracking cumulative loading limits, as long as the rate does not exceed the agronomic rate. Biosolids that meet the ceiling limits but not the pollutant concentration limits can only be applied until the amount of metals on the site have accumulated up to the cumulative limits.

The Part 503 Biosolids Rule divides biosolids into “Class A” and “Class B” biosolids in terms of pathogen levels. It also imposes a vector attraction reduction requirement, providing specific alternatives for meeting the requirement. Whether biosolids are Class A or Class B can affect MSW facility operators in several ways. Class A biosolids must undergo treatment that reduces pathogens (including pathogenic bacteria, enteric viruses and viable helminth ova) in the biosolids below detectable levels. Once these goals are achieved, Class A biosolids can be land applied without any pathogen-related restrictions at the site. Class A biosolids (but not Class B) can be used as bagged biosolids marketed to the public. Some of the treatment processes described earlier, such as composting, heat drying, and high-temperature aerobic digestion, can meet the Part 503 Biosolids Rule Class A pathogen reduction requirements if they are conducted to meet operating conditions also specified in the rule. Biosolids having the least further restrictions on beneficial use are those meeting the Class A pathogen and vector attraction reduction requirements, and the high-quality pollutant concentration limits for metals. Once these requirements are met, the biosolids can be used with no more restrictions than any other fertilizer or soil amendment product.

Class B biosolids ensure that pathogens in biosolids have been reduced to levels that are protective of public health and the environment under the specific use conditions. Site restrictions apply to Class B biosolids, which minimize the potential for human and animal contact with the biosolids until environmental factors have reduced pathogens to very low levels. Class B biosolids cannot be sold or given away in a bag or other container for land application at public contact sites, lawns, and home gardens. Class B biosolids can be used in bulk at appropriate types of land application sites, such as agricultural lands, forests, and reclamation sites, if the biosolids meet the limits on metals, vector attraction reduction, and other management requirements of Part 503. Biosolids can be used as MSW landfill cover, as long as they meet regulatory requirements in 40 CFR Part 258, which governs MSW landfills (the Part 503 Biosolids Rule does not cover biosolids that are disposed of in MSW landfills but states that biosolids disposal in MSW landfills must meet the Part 258 Landfill Rule requirements). See 40 CFR Part 503 for specific requirements, including which biosolids treatment processes are approved for Class A and B biosolids, and the Part 258 Landfill Rule for specific MSW landfill requirements. Section 2.3.3 discusses the Part 258 MSW landfill requirements specific to biosolids disposal in more detail.

homeowners for lawns and home gardens. Agricultural land application of biosolids has worked well for many communities. Application of biosolids to forest lands, which currently involves a relatively small percentage of biosolids, can help shorten pulp wood and lumber production cycles by accelerating tree growth (U.S. EPA, 1994c). At reclamation sites, biosolids help revegetate barren land and control soil erosion; relatively large amounts of biosolids are used to achieve these goals at reclamation sites. A growing market is the use of biosolids in manufactured soils, which can be used for erosion control, roadway construction, and parks (U.S. EPA, 1998a). Composted and heat dried or pelletized biosolids used on public lands, lawns, and home gardens are often sold or given away in bags or bulk quantities; these forms are usually of excellent quality (with very low levels of metals and pathogens below detection levels), are easy to store and handle, and are usually in high demand.

The value of crop or other vegetation improvements from using marketed biosolids products (such as bagged or other containerized biosolids) has been estimated at between $35 to $50 per dry ton more than the value generated by other potting media (U.S. EPA, 1995a). In some areas, such as King County, Washington, a high demand for composted biosolids products exists. Some communities, such as Austin, Texas, give away some of their composted biosolids (although a nominal cost is strongly recommended to support regional compost markets). Biosolids also have valuable properties that many commercial fertilizers cannot duplicate (e.g., the slow release of nutrients providing long-term nourishment to plants). A number of communities, such as Milwaukee with its well-known Milorganite® brand biosolids product (heat dried, not composted), have successfully marketed brand-name biosolids fertilizers or soil conditioning products. Although ventures in developing composted or further processed biosolids products involve additional costs for communities over direct land application, the sale of these products can generate revenue that offsets some of the costs. Also, communities with existing composting operations, such as for yard trimmings, may easily incorporate biosolids into their operation using yard trimmings as a bulking agent. Combining these materials to produce a biosolids compost could avoid additional costs, since a composting operation is already in place. Federal and state regulations regarding biosolids composting, however, must be taken into consideration.

Liquid or dewatered biosolids can be applied by surface spreading or, in the case of liquid biosolids, by subsurface injection. Surface application methods include spreading by farm manure spreaders, tank trucks, or special applicator vehicles. After being applied to the surface and allowed to dry partially, biosolids are commonly incorporated into the soil by plowing, discing, or other methods. Liquid biosolids may be malodorous but can be injected below the soil surface by tank trucks with injection shanks to minimize odors. At forest sites and reclamation sites, spray irrigation of liquid biosolids and special flinging of dewatered biosolids are common.

2.3.2 Incineration of Biosolids

Incineration of biosolids involves firing biosolids at high temperatures in a combustor or combustion device. The volatile organic materials in the biosolids are burned in the presence of oxygen. Incineration reduces biosolids to a residue primarily consisting of ash, which is approximately 20 percent of the original volume. The incineration process destroys virtually all of the volatile solids and pathogens and degrades most toxic organic chemicals, although compounds such as dioxin may be formed, and products of incomplete combustion must be controlled. Metals are not degraded and are concentrated in the ash and in the particulate matter that is contained in the exhaust gases generated by the process. Air pollution control devices, such as high-pressure scrubbers, are required to protect air quality. See Box 2 for information on the regulations affecting biosolids incineration. Nonhazardous biosolids incinerator ash can be disposed of in a MSW landfill as allowed by 40 CFR Part 258 Landfill Rule. The ash also can be used in aggregate (e.g., concrete) production, as a fluxing agent in ore processing, or for other purposes such as an athletic field amendment (see Section Five).

The types of incinerators most commonly used are multiple-hearth and fluidized-bed furnaces. Fluidized-bed furnaces, however, are known to have fewer problems with emissions than multiple-hearth units because of their more advanced technology resulting in more uniform combustion of biosolids. Common types of air pollution control devices include wet scrubbers, dry and wet electrostatic precipitators, fabric filters (all of which control particulates), and afterburners (which can control releases of partially burned organics). Some municipalities opt for biosolids incineration when land is scarce or unsuitable for land application.

Box 2: Regulations Affecting the Incineration of Biosolids

Several regulatory considerations apply to facilities that incinerate biosolids. The 40 CFR Part 503 Biosolids Rule includes pollutant limits for metals in emissions that effectively become site-specific limits on metals in biosolids that are incinerated; limits on total hydrocarbons or carbon monoxide in emissions; general requirements and management practices; frequency of monitoring requirements; and recordkeeping and reporting requirements. If biosolids incinerator ash is applied to land other than in a MSW landfill, regulations in 40 CFR Part 257 must be followed. Any incinerated waste that meets the definition of a hazardous waste must meet regulations in 40 CFR Parts 261 through 268 for hazardous wastes. Additionally, if biosolids and MSW are cofired and MSW accounts for less than 30 percent of the mixture, the mixture is considered auxiliary fuel and must meet Part 503 requirements for incineration. If the percentage of MSW in a biosolids/MSW mixture is greater than 30 percent, then the mixture is not regulated as an auxiliary fuel under the Part 503 Biosolids Rule but rather is regulated as MSW under 40 CFR Parts 60 and 61. The equipment used in incinerators that cofire biosolids with other wastes generally must be specially designed for this purpose (e.g., include flash dryers and separate burners) to handle the moisture content and odor potential of biosolids successfully. In the near future, incinerators also will be subjected to regulation under provisions of the Clear Air Act that are more stringent and are based on what is technically achievable.

In some cases, municipalities use incinerators as standby units on an as-needed basis for use when other biosolids management options cannot be implemented.

The type of biosolids incinerated affects incineration efficiency. Due to their higher volatile solids content (i.e., heat content), for example, biosolids from primary wastewater treatment processes (see Table 2-1) are more suitable for incineration than those that have undergone secondary treatment or above. Biosolids from secondary wastewater treatment processes are more difficult to incinerate because of their lower volatile solids content and the higher water content. Biosolids dewatering is required prior to incineration. Biosolids incinerator ash can be recovered and used in aggregate or can be used for other products such as an athletic field amendment (see case studies in Section Five).

Only a few facilities in the United States currently cofire biosolids with MSW (communication with Steven Levy, U.S. EPA, October, 1997). This practice is so rarely used that, for the purposes of this report, we assume all incineration of biosolids discussed in Sections Three and Four to take place in biosolids-only incinerators.

Although biosolids incinerators require auxiliary fuel, many facilities that incinerate biosolids include energy recovery as part of the process (communication with Bob Bastian, U.S. EPA, October, 1997). Most of these facilities use the energy generated within the facility for the incineration process itself (some facilities have claimed to be autothermal, or self-sufficient in producing and using their own energy) or for energy for other facility processes. A few facilities have in the past sold at least part of the energy they produced from the incineration process. In many cases, air quality requirements determine incinerator operation to some extent because the requirements are temperature-based (i.e., an afterburner to raise the temperature of exit gases might be needed to destroy unburned hydrocarbons) and often cannot be met economically unless energy recovery is included in the process. Numerous facilities that incinerated biosolids have closed over the past decade because other biosolids management options became more publicly acceptable or less expensive, even when the facilities recovered energy.

To the extent that biosolids are successfully being used for energy recovery and to the extent that energy recovery might be considered a beneficial use, the quantities of biosolids that are estimated in this report to be beneficially used might be somewhat understated. Defining incineration as a disposal method, however, is consistent with the Part 503 Biosolids Rule, which categorizes biosolids incineration as a disposal method, since that is the primary purpose of incinerating biosolids.

2.3.3 Surface Disposal and Landfilling

Most biosolids that are disposed of in or on land are landfilled with MSW. This report combines most discussions of surface disposal (as covered by the Part 503 Biosolids Rule for biosolids-only disposal in or on land) and landfilling (defined here as disposal of biosolids in MSW landfills, which is covered by the Part 258 Landfill Rule rather than by Part 503). See Box 3 for information on the regulations affecting surface disposal on land and landfilling of biosolids in MSW landfills.

Surface disposal is defined by the Part 503 Biosolids Rule as biosolids placed on an area of land where only biosolids are placed for final disposal. It does not include biosolids that are placed on land for either storage (generally less than 2 years) or treatment (e.g., lagoon treatment for pathogen reduction). It involves landfilling of biosolids in monofills (biosolids-only landfills), disposal in permanent piles or lagoons used for disposal (rather than treatment or temporary storage), and dedicated surface disposal practices. The difference between surface disposal and land application primarily involves the application rate. If biosolids are spread on land at greater than the agronomic rate, then the ability of the cover crop to retain nitrogen might be exceeded, and the excess nitrogen could migrate through the soil and contaminate ground water. Any time the application rate exceeds the agronomic rate (except as permitted by the permitting authority for reclamation sites), EPA considers the practice to be surface disposal, and the site must comply with all of the management practices outlined for surface disposal in the Part 503 Biosolids Rule, including ground-water monitoring. If, however, the applier reduces the application rate or changes the cover crop from a low-nitrogen-demand crop to a high-nitrogen-demand crop, and the practice meets Part 503 requirements for land application (assuming the land application criteria for metals concentrations and pathogens and vectors are met; see Box 1), then the practice is considered land application.

At the time the National Sewage Sludge Survey was conducted, biosolids from most POTWs practicing surface disposal were determined to be able to meet the Part 503 pollutant concentration criteria for land application, and, in many cases, the biosolids were being applied at rates that could be considered agronomic rates (U.S. EPA, 1993a). Therefore, the practice of spreading biosolids on land for disposal purposes was nearly eliminated by the Part 503 Biosolids Rule because: 1) the cost of meeting surface disposal management requirements (including ground-water monitoring) is usually much higher than that for meeting land application requirements and 2) most operations could be easily adapted to meet the Part 503 definitions of land application.

The vast majority of biosolids currently reported as either surface disposed or landfilled are likely to be disposed of in MSW landfills.[3] The small amounts of biosolids reported as surface disposed or landfilled that are not disposed of in MSW landfills are likely primarily disposed of in biosolids-only monofills (i.e., landfills dedicated to accepting only biosolids). Monofilling, possibly the most common surface disposal technique covered by the Part 503 Biosolids Rule, typically is undertaken using a series of unlined trenches dug into the ground, into which dewatered biosolids (meeting concentration limits imposed by Part 503 for unlined surface disposal units) are placed and then covered with soil. Other techniques less commonly used include fill mounds, area fill layers, and diked containment.

[3]This conjecture is further substantiated by communication with Bob Bastian, U.S. EPA, May, 1997 and by information in *BioCycle* (1998), which indicates that among the 34 surveyed states that provided adequate data, less than 2 percent of biosolids are reported to be surface disposed in biosolids-only monofills.

Box 3: Regulations Affecting the Surface Disposal and Landfilling of Biosolids

The Part 503 Biosolids Rule regulates the surface disposal of biosolids other than landfilling of biosolids with MSW in an MSW landfill, which is required to meet the Part 258 Landfill Rule. According to Design, Operation and Closure of Municipal Solid Waste Landfills (U.S. EPA, 1994b), all biosolids disposed in MSW landfills must pass the paint-filter liquids test (dewatering biosolids to about 20 percent solids or more will generally meet this goal). Furthermore, the biosolids cannot contain more than 50 parts per billion of polychlorinated biphenyls (PCBs) (40 CFR Part 761) and must not meet the definition of hazardous wastes under the Resource Conservation and Recovery Act (RCRA) (that is, they must not meet the definition of hazardous waste as defined by RCRA or the Toxicity Characteristic Leachate Procedure test).

Biosolids used as MSW landfill cover should be dewatered to achieve soil-like characteristics. The Part 258 Landfill Rule requires that the daily MSW landfill cover consist of 6 inches of earthen material (or alternative materials or thickness approved by the state) and that the solid waste be covered at the end of each day or more frequently as needed to control disease vectors, fires, odors, blowing litter, and scavenging. Biosolids can be used as part of a final MSW landfill cover, which must meet the Part 258 Landfill Rule cover criteria for permeability, infiltration, and erosion control.

For surface disposal in biosolids-only facilities, Part 503 requires that the site meet certain locational restrictions similar to the site restrictions in the Part 258 Landfill Rule. Provisions for closure and postclosure care must be made, and a plan for leachate collection (if the unit is lined), methane monitoring, and public access restrictions must be developed. If the surface disposal unit is unlined, the biosolids must meet concentration limits on arsenic, chromium, and nickel. Also, the surface disposal unit must meet management requirements similar to those for MSW landfills. These management practices include requirements for runoff collection, leachate collection and disposal (if the unit is lined), vector control, methane monitoring, and ground-water monitoring or certification, and restrictions on public access, growing of crops, and grazing of animals. See the Part 503 Biosolids Rule and U.S. EPA, 1994a for more details.

Section Three

Generation, Use, and Disposal of Biosolids in 1998

3.1 Generation of Biosolids in 1998

This report uses the National Sewage Sludge Survey (NSSS) estimate of the quantity of biosolids used or disposed of in 1988 and data on wastewater flow between 1988 and 1996 from the Needs Surveys conducted during those years to estimate the quantity of biosolids generated in 1998. This estimate was made on the basis of increased wastewater flow since 1988 and on the assumption that biosolids generation per gallon of wastewater has remained approximately the same from 1988 to 1998. (See the Appendix for a detailed discussion of the methodology used in this report, the sources used, the assumptions made to derive this estimate, and a presentation of intermediate results.) On the basis of this approach, we estimate that 6.9 million dry tons of biosolids were generated in 1998. Table 3-1 presents a breakdown of this estimate to show the quantities of biosolids estimated to have been generated by primary-only treatment POTWs or secondary-or-above treatment POTWs and by privately or federally owned treatment works.

Table 3-1
Estimates of Biosolids Generation for Use or Disposal (1998)

Treatment Group	1998 Biosolids Generation (million U.S. dry tons)
Primary-Only Treatment POTWs	0.5
Secondary-or-Above Treatment POTWs	6.3
Privately and Federally Owned Treatment Works	0.1
Total	6.9

Source: See Appendix A.2.2.

3.2 Biosolids Management Practices in 1998

This report primarily used the 1997 Water Environment Federation (WEF) report results (with some modifications; see the Appendix) to divide biosolids management practices into use and disposal categories (see Section 1.2). Categories of management practices considered beneficial use include land application, composting and other approaches to further processing, and other beneficial use. Composting and further processing and stabilization is a special category partly created out of WEF survey responses indicating “treatment” or other related management practices including responses such as fertilizer, lawns and gardens, potted growing media, soil amendments, composting, or pelletizing. Generally, biosolids receiving further processing (also referred to as “advanced treatment” in this report) are considered likely to have met Class A pathogen and vector reduction requirements (see Box 1 in Section Two). We consider the ultimate end use of these biosolids to be primarily land application. We included survey responses indicating landfill cover or aggregate in the “other beneficial use” category. The Part 503 Biosolids Rule does not regulate landfill cover if it is being placed on MSW landfills; however, we consider landfill cover to be a beneficial use for the purposes of this report. Therefore, the amount of biosolids used for landfill cover or as aggregate is accounted for within the total amount of biosolids beneficially used and not within the disposal totals.

Disposal, for the purposes of this document, as discussed in Section Two, includes surface disposal, landfilling, and incineration. Additionally, in this report, we have defined an “other” category, which includes WEF survey responses of any unidentified processes. We have placed quantities included in this very small category within the disposal totals.

3.2.1 Beneficial Use of Biosolids in 1998

Table 3-2 and Figure 3-1 present a breakdown of the various biosolids management options, which are categorized as either a beneficial use option or a disposal option. As the table shows, 60 percent of all biosolids generated in 1998 were land applied, received advanced treatment and then land applied, or were otherwise beneficially used. This category of “other beneficial use,” which accounts for 7 percent of all biosolids generated, intends to capture and include as beneficial use the fraction of biosolids that might be used as alternative daily landfill cover, as part of a final landfill cover, or as aggregate.[4] We assume for the purposes of this report that the land application category is generally associated with Class B biosolids and the advanced treatment category is associated with Class A biosolids. Out of a total of 6.9 million dry tons, we estimate that 2.8 million dry tons have been land applied after being treated to a Class B pathogen status. We estimate an additional 0.8 million dry tons to have been beneficially used after further treatment, such as composting, advanced alkaline

[4]This total differs from the estimate, made by Bastian in 1997, that only 54 percent of all biosolids generated were beneficially used. The difference is due to the inclusion in this report of an "other beneficial use" category (i.e., landfill cover and aggregate) accounting for 7 percent of the total amount contributing to the beneficial use total of 60 percent.

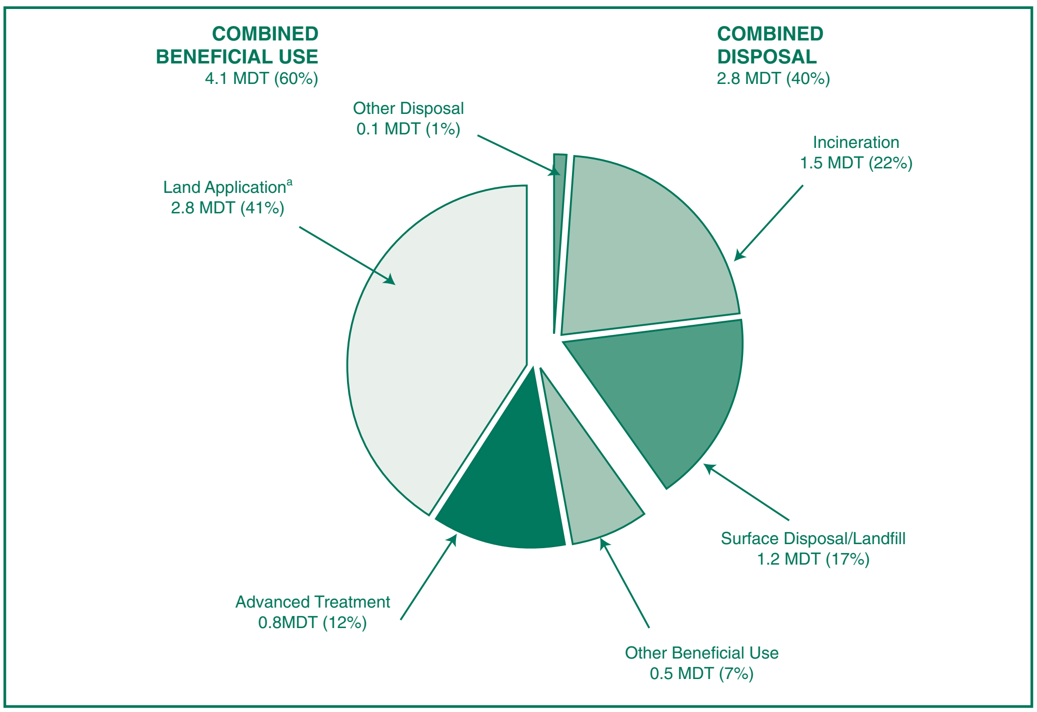
stabilization, or heat treatment, and that 0.5 million dry tons have been beneficially used in another manner for a total of 4.1 million dry tons. See the Appendix for how we estimated these quantities.

Table 3-2
Estimates of Biosolids Use and Disposal

Estimate (millions)	Beneficial Use				Disposal				
	Land Application[a]	Advanced Treatment[b]	Other Beneficial Use	Total	Surface Disposal/ Landfill	Incineration	Other	Total	Total
1998 Dry Tons	2.8	0.8	0.5	4.1	1.2	1.5	0.1	2.8	6.9
Percent of Total	41%	12%	7%	60%	17%	22%	1%	40%	100%

Note: Numbers may not add up properly due to rounding.
Source: See Appendix A.3.
[a]Without further processing or stabilization such as composting.
[b]Such as composting.

Figure 3-1
Estimates of Biosolids Use and Disposal (1998)



MDT (1998) = millions of dry tons
Source: See Appendix A.3.
[a]Without further processing or stabilization such as composting.

3.2.2 Disposal of Biosolids in 1998

Table 3-2 also presents a breakdown of the disposal categories. We estimated that 17 percent of all biosolids were surface disposed or landfilled, 22 percent were incinerated, and 1 percent were disposed of in some unidentified manner. Thus, 40 percent (2.8 million dry tons) of all biosolids generated in 1998 were disposed of primarily in landfills (1.2 million dry tons) or incinerated (1.5 million dry tons).[5]

3.2.3 Amount of Biosolids Managed by MSW Facilities in 1998

Out of the total 6.9 million dry tons of biosolids generated in 1998, we estimate that a total of 1.2 million dry tons were disposed of at MSW landfills, and 0.2 million tons of treated biosolids were handled at MSW facilities as landfill cover (daily or final). Additionally, MSW facilities[6] might have composted biosolids either on or off a landfill site. The total amount of biosolids that might have been composted by MSW facilities is not known at this time, but we estimate the total amount to have been 0.4 million dry tons based on the assumptions listed below. Thus, we estimate that possibly 1.4 to 1.8 million dry tons, or 20 to 26 percent of biosolids generated in 1998, might have been managed by MSW facilities after processing by POTWs. As noted, these estimates depend on the following assumptions:

- All surface-disposed or landfilled biosolids are disposed of in MSW landfills. This assumption is reasonable given the small amount of biosolids believed to be disposed of in monofills, piles, or surface disposal sites (see Section Two).[7]
- No biosolids are coincinerated with solid waste. This is a reasonable assumption because coincineration is not a common practice.[8]
- We assume that the advanced treatment category is split such that half is managed at MSW facilities (landfill, commercial, noncommercial, or municipal operations, as defined above). MSW facilities are assumed to include any composting facilities that handle both organic MSW (e.g., yard trimmings) and biosolids. The actual percentage of the advanced treatment category (composted) biosolids managed by MSW facilities is not known at this time, and further research is recommended.

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[5]The quantity of biosolids incinerated might be overstated, but supporting information is inadequate to adjust the data; see discussion in the Appendix.

[6]An MSW facility is defined for the purposes of this report to include: 1) any facility, such as an MSW landfill, that handles MSW; 2) any commercial or noncommercial operation that composts biosolids and organic MSW suitable for composting (e.g., yard trimmings); and 3) municipal operations not associated with MSW landfills, such as parks departments, public works departments, or POTWs, that manage composting programs using both organic MSW and biosolids.

[7]Also based on communication with Bob Bastian, U.S. EPA, May, 1997.

[8]Based on communication with Steven Levy, U.S. EPA, October 1997, and Bob Bastian, U.S. EPA, October 1997.

Section Four

Trends and Projections for Biosolids Generation, Use, and Disposal

A variety of factors have influenced biosolids generation and use over the years. Advancements in wastewater and biosolids treatment technologies, including wastewater pretreatment, pollution prevention programs, and population growth, have resulted in increased volumes of higher quality biosolids (Stehouwer and Wolf, 1998). Increases in biosolids amounts and improvements in quality are only part of the story, however. Federal and state regulations and guidance, in particular the Part 503 Biosolids Rule, have encouraged recycling and use of biosolids rather than disposal.[9] Additionally, a number of factors have contributed to increased biosolids use (see Section Five). These factors include outreach and marketing efforts, high costs for disposal of biosolids in some locations, bans on disposal of biosolids in landfills (such as in New Jersey), landfill capacity concerns, closures of landfills following implementation of landfill regulations, bans of yard trimmings in landfills, and continuing research into the safe beneficial use of biosolids. In some areas of the country, however, biosolids use has temporarily decreased. In these areas, landfill costs are relatively low because of the presence of very large landfills (megafills). This situation is causing some beneficial use operations to begin landfilling their biosolids. It is not yet clear, however, whether this factor will affect the overall trend away from disposal of biosolids. This section presents a summary of these and other factors affecting current trends in biosolids management and includes specific projections for biosolids generation, use, and disposal through 2010.

4.1 Generation

The U.S. population and the population served by municipal sewers have increased dramatically over the past 20 years. These increases have

[9]Three federal beneficial use policies have had an important influence. See U.S. EPA, FDA, and USDA 1981; Federal Register, Vol. 49, No. 114, pp. 24358-59, July 12, 1984; and Federal Register, Vol. 50, No. 138, pp. 33186-88, July 10, 1991.

contributed to an increase in the volume of biosolids produced since 1972 (nearly a 50 percent increase; see Section Two). As population levels continue to increase, we expect the generation of biosolids to increase (Bastian, 1997).

Moreover, during the past 20 years, POTWs increasingly have been treating wastewater at more advanced levels. By 1988, over 75 percent of the U.S. population was served by POTWs providing secondary wastewater treatment as mandated by the Clean Water Act. By 1996, this figure had increased to over 90 percent (U.S. EPA Needs Surveys, 1988 to 1996). Also, some secondary wastewater treatment methods can produce additional amounts of biosolids over that generated by primary treatment alone. The total amount of biosolids produced annually has increased at a somewhat greater rate than the increased U.S. population being served by sewers (see Appendix calculations and projections). These increases in quantity have been accompanied by improved environmental quality of biosolids due to the greater prevalence of pretreatment and pollution prevention programs undertaken by industrial wastewater generators. The physical quality of biosolids also has improved because of advanced mechanical dewatering equipment, automated process control systems, aeration systems, and odor control systems. New technologies such as these have allowed for lower water content, less odor, and easier handling of biosolids.

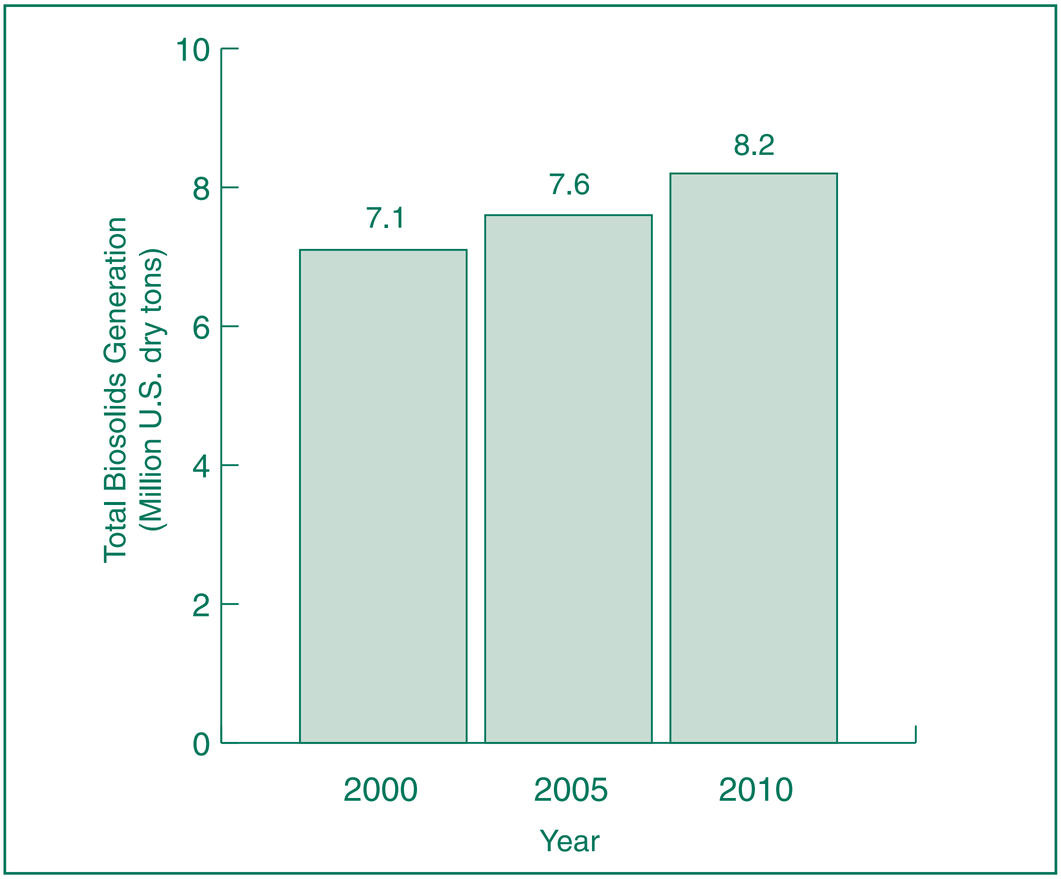
The trends in wastewater flow increases during 1986 to 1996 show an average of a 4 percent per year decrease in wastewater flow at POTWs using only primary treatment, while wastewater flow at POTWs using secondary or higher levels of treatment has increased about 2 percent per year (see the Appendix). Assuming that these trends will continue into the future, and using the same methodology used to estimate 1998 biosolids generation, the expected biosolids generation amounts in 2000, 2005, and 2010 are shown in Table 4-1 and Figure 4-1 (see the Appendix for methodology). Future biosolids production is expected to increase from 6.9 million dry tons in 1998 to 7.1 million dry tons in 2000, 7.6 million dry tons in 2005, and 8.2 million dry tons in 2010. This represents a 19 percent increase from 1998 to 2010. These increases are largely due to anticipated increases in population served and, to a lesser extent, the increase in POTWs using secondary treatment and the subsequent slight increases in quantities of biosolids produced.

Table 4-1
Projections of Biosolids Generation for Use or Disposal in 2000, 2005, and 2010

Year	Total (million U.S. dry tons)
1998	6.9
2000	7.1
2005	7.6
2010	8.2

Source: See Appendix A.5.

Figure 4-1
Projections of Biosolids Generation for Use or Disposal in 2000, 2005, and 2010



Source: See Appendix A.5.

4.2 Use and Disposal

The following sections discuss general trends in use and disposal that are expected to continue into the future.

4.2.1 Use Trends

Just as the generation of biosolids has increased over the past 20 years, so has the use of biosolids. There are three major reasons for this increase. First, regulatory influences on both the federal and state levels have encouraged the beneficial use of biosolids, either directly through guidance and federal policies on beneficial use or indirectly because of stringent and higher-cost requirements for disposal practices (e.g., incineration and landfilling). Second, better biosolids research and technology also have helped alleviate public concern regarding the human health and environmental impacts of biosolids. Third, outreach, education, and marketing efforts have been improving public perceptions in some areas of the United States about the beneficial use of biosolids, although public acceptance problems persist in other areas. The potential for a growing positive acceptance of beneficial use of biosolids could lead to increasing biosolids recovery in the future.

Regulatory influences on biosolids use include the indirect effects from the Clean Water Acts of 1977 and 1986 and the more direct effects of the Part 503 Biosolids Rule. The Clean Water Act mandated more active federal involvement in biosolids management, which previously had been handled primarily at a state level. Effluent restrictions were set by the National Pollutant Discharge Elimination System (NPDES) program for industrial facilities discharging to POTWs. As a result, POTW influent and the resulting biosolids now have lower levels of contaminants. Biosolids quality has dramatically improved since the 1970s. Regulations promulgated in response to the 1988 Ocean Dumping Ban Act and the Clean Water Act (i.e., Part 503) prohibited ocean dumping of biosolids and imposed comprehensive controls on biosolids use and disposal practices.

More importantly, Part 503, codified in 1993, clearly defines biosolids quality requirements for use or disposal and has become a useful tool for biosolids managers in marketing efforts (U.S. EPA, 1994a). The Part 503 Biosolids Rule helps biosolids managers identify "exceptional quality biosolids" (i.e., biosolids that meet the most stringent metals limits and Class A pathogen and vector control requirements—see Box 1 in Section Two). Exceptional quality biosolids are subject only to the same regulations as any other fertilizer product; thus, the rule provides a useful public relations tool that has opened the door for greater use of biosolids as fertilizer and soil conditioner and has also expanded potential markets for products such as compost made from biosolids. The Part 503 rule has encouraged POTWs to treat biosolids to a higher quality level and provide for the least constraints on use. Furthermore, for disposal methods, Part 503 requires relatively expensive pollution control equipment and/or management practices, such as ground-water monitoring, further encouraging biosolids recycling and use options rather than disposal.

The increase in biosolids use associated with the implementation of the Part 503 Biosolids Rule is measurable according to a study performed by *BioCycle* magazine. This study notes that 37 states have regulations in place that are the same or more stringent than Part 503 (*BioCycle,* 1997). Thirty-four states regulate exceptional quality biosolids in the same way they do fertilizers. Both of these regulatory conditions provide incentives for biosolids recovery and reuse. Thirty states have increased the beneficial use of biosolids, and many community programs have encouraged biosolids use. Composting programs on the community level, such as in Portland, Oregon; Palm Beach County, Florida; and Hampton, New Hampshire, have lowered the cost of composting biosolids (Snow, 1995) by combining biosolids with yard trimmings in their composting operations. Additionally, composting facilities often charge a tipping fee to receive yard trimmings, which offsets processing costs.

During the development of the Part 503 Biosolids Rule, EPA extensively researched the risks of beneficially using biosolids and determined that risks from properly managed biosolids are negligible (U.S. EPA, 1992a). This research has allowed EPA to set standards that are protective of human health and the environment. An independent report by the National Research Council in 1996 titled *Use of Reclaimed Water and Sludge in Food Crop Production* concluded that established numerical limits (in the Part 503 rule) on concentrations of pollutants added to cropland by biosolids are adequate to ensure the safety of crops produced for human consumption (National Research Council, 1996). These findings also tend to encourage beneficial use.

Another factor influencing biosolids recycling is public perception, which plays an important role in biosolids marketability. With the evolution of regulatory standards for biosolids, marketing and promotion of biosolids or products made from biosolids have been made possible. Although public education on the attributes of beneficial use has increased public acceptance, increased public awareness also has the tendency to generate skepticism about the risks of biosolids use, public health, and the environment. Public opposition to biosolids use, whether legitimate or unfounded, can arise from any change to the status quo.

The ability to market biosolids products will be determined by the public's perception of the safety and value of biosolids recovery. In an effort to improve public acceptance on a national scale and to increase the beneficial use of biosolids, the National Biosolids Partnership has been established and, with the support of Congress, will be working with stakeholders to develop an Environmental Management System (EMS) for Biosolids. The National Biosolids Partnership consists of representatives from the Water Environment Federation, the Association of Metropolitan Sewerage Agencies, EPA, states, the U.S. Department of Agriculture, and other stakeholders. The EMS is a voluntary program designed to help ensure the responsible management of biosolids from generation of solid wastewater treatment residuals through the further treatment, transport, storage, and use of the resulting biosolids. Successful EMS development and ultimate implementation depends in great part on the participants and the development process. Those stakeholders involved in this process include the public; generators; land appliers; farmers; academics; federal, state, and local governments; and other interested parties. At a minimum, entities who pledge to follow the EMS code must be in compliance with all applicable rules as well as managing nutrients and controlling nuisances such as odors, noise, and traffic. It is envisioned that the EMS will have:

- A code of good practices that defines broad goals to guide the operation of biosolids management programs at all facilities and for all projects that adopt an EMS.
- A manual of good practice that describes the full range of practices available to facilities and projects that choose to implement an EMS. Each project or facility will select from the manual those specific practices that are appropriate to its situation.
- A set of procedures that can be used by all entities who pledge to meet the code in designing and implementing their own EMS.

- An ongoing program of one or more forms of independent third-party verification and advisory input to insure continuing effective implementation based on the code.
- A training program to help entities understand what meaningful participation in the EMS will be.

For more information regarding public acceptance, Section Five of this report presents a number of issues concerning biosolids use that can negatively affect public perceptions (e.g., human health risks). Section Five also addresses how these issues can be dealt with effectively with a careful and well planned biosolids management program. In addition, several case studies are presented that highlight successful beneficial use/composting programs.

4.2.2 Disposal Trends

Disposal of biosolids is expected to decrease because of regulatory influences, voluntary improvements in biosolids quality, and the resulting increase in biosolids use. Regulatory influences include the increased restrictions on incineration, surface disposal, and landfilling in the Part 503 Biosolids Rule, the Part 258 Landfill Rule, and various state requirements, which also have driven up the costs of these disposal methods (U.S. EPA, 1993a). In some municipalities, however, decreases in landfill costs are causing shifts toward increased landfilling and reductions in biosolids recycling. This trend is evident primarily among municipalities using landfills with excess capacity. The long-term effects of this factor on biosolids beneficial use is not yet known at this early stage.

As incineration becomes more costly, disposal of biosolids through this method is expected to decrease. Incineration is a costly means of disposal and is primarily used in large urban areas (proposed Part 503 rule, *Federal Register*, Vol. 54, No. 23, February 6, 1989, pp. 5476-5902; U.S. EPA, 1993a). Public concern about the environmental and health impacts of incineration has made this disposal option even more costly and difficult to undertake. Public resistance to incineration is so great that no new incinerators have been built in recent years, and expansions or upgrades to existing incinerators are difficult to get approved (Bastian, 1997).

Any increased costs of biosolids disposal also are expected to promote beneficial use. MSW landfills built to meet the Part 258 Landfill Rule requirements incorporate liners, gas control, leachate control, and plans and funding for monitoring and long-term care after closure, which makes them more expensive than landfills built prior to issuance of the Part 258 Landfill Rule (Regulatory Impact Analysis (RIA) for 40 CFR Part 258 [U.S. EPA, 1991]). The national average tipping fee is expected to rise from $35 per ton (prior to the Part 258 Landfill Rule implementation in 1997 dollars) to $38 per ton (U.S. EPA, 1998b). Other analyses, however, have shown no increase in tipping fees in 1998, and according to these analyses, a very slight downward trend is expected to hold for the next few years (Glenn, 1998). Where local increases in tipping fees are occurring, however, communities will be encouraged to consider diverting high-volume, readily compostable organic residues from their landfills. Tipping fees around the country range anywhere from $15 per ton (Texas) to over $100 per ton (New Jersey) (U.S. EPA, 1999).

4.2.3 Use and Disposal Projections

Based on the above discussion of expected trends in biosolids use and disposal, Table 4-2 provides projections on the percentages of biosolids that will be used or disposed of in 2000, 2005, and 2010. The use and disposal of biosolids were estimated in dry tons for those years (see Table 4-3) in an effort to characterize trends in biosolids use and disposal methods more accurately. As shown in Table 4-2, beneficial use of biosolids is expected to increase from 60 percent in 1998 to 63 percent in 2000, 66 percent in 2005, and 70 percent in 2010. Thus, by 2010, we estimate that disposal might only account for about 30 percent of all biosolids generated.

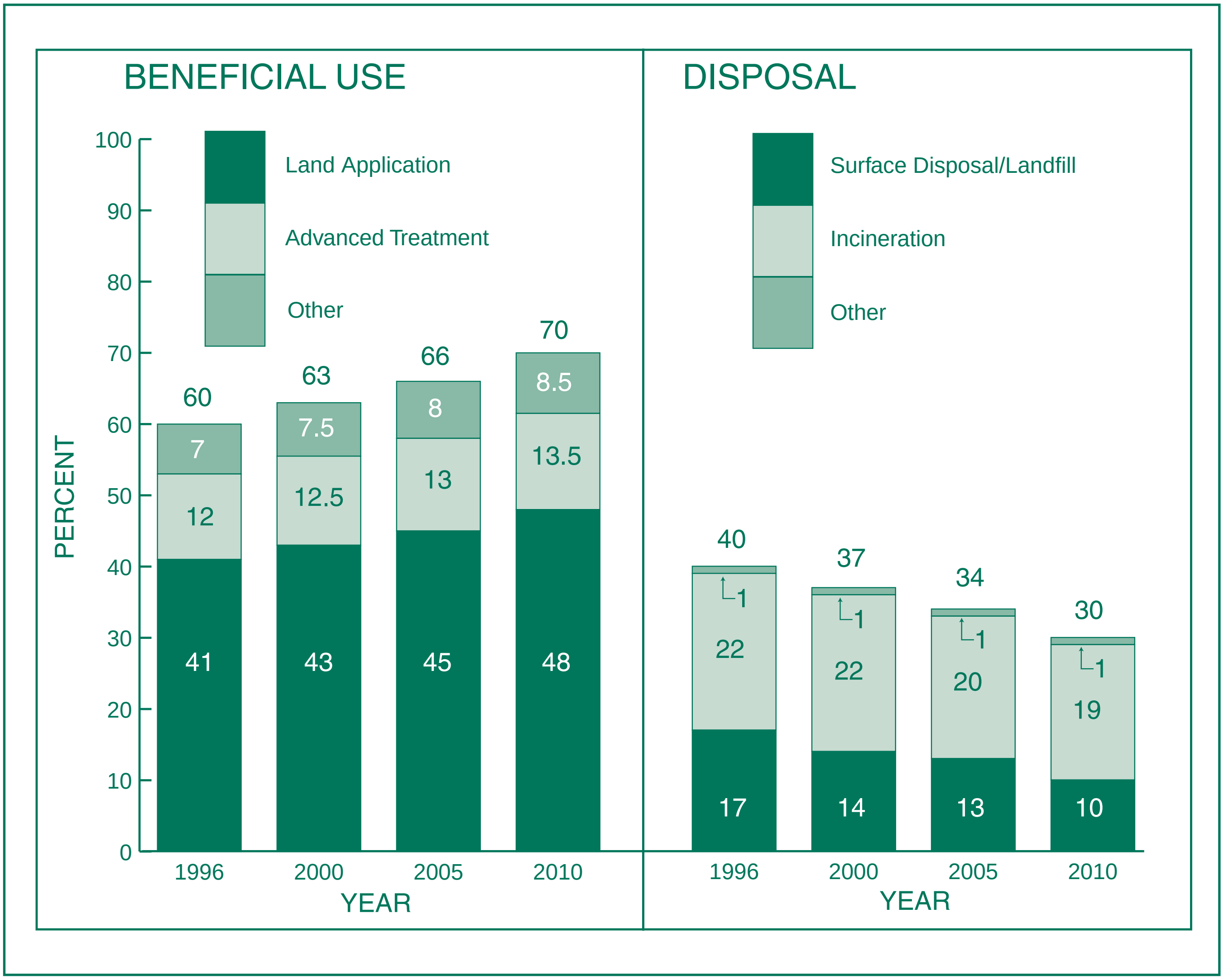
Table 4-2
Projections of Use and Disposal in 2000, 2005, and 2010

Year	Beneficial Use				Disposal			
	Land Application	Advanced Treatment	Other Beneficial Use	Total	Surface Disposal/ Landfill	Incineration	Other	Total
1998	41%	12%	7%	60%	17%	22%	1%	40%
2000	43%	12.5%	7.5%	63%	14%	22%	1%	37%
2005	45%	13%	8%	66%	13%	20%	1%	34%
2010	48%	13.5%	8.5%	70%	10%	19%	1%	30%

Source: See Appendix A.5.

Table 4-3 and Figure 4-2 below show estimated quantities of biosolids, in millions of U.S. dry tons, projected to be used or disposed of based on the percentages in Table 4-2 and the quantities of biosolids projected to be generated. The amount of biosolids estimated to be used beneficially is expected to increase to 4.5, 5.0, and 5.7 million dry tons in 2000, 2005, and 2010, respectively, with 2.6, 2.6, and 2.5 million dry tons, respectively, being disposed of. A positive trend in the beneficial use of biosolids is expected to continue in the future, while the trend toward disposal decreases slightly.

Figure 4-2
Projections of Use and Disposal for 2000, 2005, and 2010



Source: See Appendix A.5.

Table 4-3
Projections of Biosolids Use and Disposal in 2000, 2005, and 2010 (million U.S. dry tons)

Year	Beneficial Use				Disposal				Total
	Land Application	Advanced Treatment	Other Beneficial Use	Total	Surface Disposal/ Landfill	Inciner-ation	Other	Total	
2000	3.1	0.9	0.5	4.5	1.0	1.6	0.1	2.6	7.1
2005	3.4	1.0	0.6	5.0	1.0	1.5	0.1	2.6	7.6
2010	3.9	1.1	0.7	5.7	0.8	1.5	0.1	2.5	8.2

Note: Numbers may not add up properly due to rounding.
Source: See Appendix A.5.

The amount of biosolids going to MSW facilities, as defined in Section Three,[10] in the years 2000, 2005, and 2010 reach 1.6, 1.7, and 1.6 million dry tons,[11] respectively, with declines in landfilled biosolids being offset by increases in use of biosolids for landfill cover and in composting.

Therefore, MSW facilities are likely to be handling about 1.6 million dry tons of the 7.1 million dry tons generated in 2000 (23 percent), 1.7 million dry tons of the 7.6 million dry tons generated in 2005 (22 percent), and only about 1.6 million dry tons of the 8.2 million dry tons generated in 2010 (20 percent). These figures include amounts of biosolids disposed of in MSW landfills, used for landfill cover, or composted for sale or given away to farmers, contractors, or the general public.

[10]An MSW facility is defined for the purposes of this report to include: 1) any facility, such as an MSW landfill, that handles MSW, 2) any commercial or noncommercial operation that composts biosolids and organic MSW suitable for composting (such as yard trimmings), and 3) municipal operations not associated with MSW landfills, such as parks departments, public works departments, or POTWs, that manage composting programs using both organic MSW and biosolids.

[11]The quantity of biosolids handled by MSW facilities is estimated to rise slightly by 2005 because the upward trend in beneficial use offsets declines in disposal, but at varying rates over the years. The categories of biosolids considered to be managed by MSW facilities include the surface disposal and landfill category and half of the advanced treatment category. See Appendix for more details of these calculations.

Section Five

Beneficial Use of Biosolids

5.1 Overview of Beneficial Use

The beneficial qualities of biosolids as a soil enhancement are generally recognized. When added to soil, biosolids contribute nutrients and improve soil properties. Depending on agricultural needs, these benefits can be even greater with composted biosolids, which enhance the physical, chemical, and biological properties of soil. Noncomposted biosolids have a high nutrient availability and decompose and mineralize quickly and easily in soils. This rapid decomposition of land-applied biosolids can provide large amounts of nitrogen and phosphorous for immediate use by crops. Composted biosolids, on the other hand, retain highly stable organic materials that decompose at a slow rate, therefore releasing nutrients at a slower and steadier rate than noncomposted biosolids (USDA, 1998). Composted biosolids thus provide a long-term source of slow-release nutrients.

Biosolids compost helps ensure pH stability; improves soil water-holding capacity, aeration, and structural stability; increases resistance to water and wind erosion; and improves root penetration. By promoting beneficial microorganisms, compost reduces attack by parasites, promotes faster root development, contributes to higher yields of agricultural crops, and reduces reliance on pesticides, herbicides, and fungicides. Furthermore, compost's ability to improve the water-holding capacity of soil and fix nitrogen into a form that can be used by plants reduces the potential for nonpoint-source pollution, such as that associated with applications of commercial fertilizers. Compost also contributes to water conservation by reducing water loss from percolation, evaporation, and runoff. In addition, compost can be used to bioremediate many toxic contaminants in soil (Garland, et al., 1995; U.S. EPA, 1997a; U.S. EPA, 1998a).

According to the *Organic Materials Management Strategies* report (U.S. EPA, 1998b), the Composting Council estimated the potential demand for compost to be over 1 billion cubic yards per year (based on 1992 data). The report describes nine markets for compost: agriculture, silviculture (forests), sod production, residential retail, nurseries, delivered topsoil, landscaping, landfill cover, and surface mine reclamation. In practice, biosolids compost is more commonly used by nurseries, landscapers, and soil blenders rather than for agricultural purposes. Nevertheless, in its analysis, the Composting Council concluded that the demand for compost in agriculture and silviculture alone could exceed current and potential supplies. While cost is a constraint with regard to processing, transportation, and bulk application equipment, the primary constraint to increased use of compost by these markets is the generation of odors during production.

Compost is just one form of biosolids that can be beneficially used, however. The combined potential of using either composted or noncomposted biosolids is great. By addressing the environmental and public health issues related to biosolids, the Part 503 Biosolids Rule also has greatly encouraged land application of many other types of biosolids, including advanced alkaline stabilized, heat-treated, and pelletized biosolids, as well as less highly processed liquid biosolids and biosolids cake. While there is a trend toward the beneficial use of biosolids, this trend is sometimes constrained, principally by lack of public acceptance, as described below.

5.2 Potential Barriers to Increased Beneficial Use

Several factors limit the potential for expanding the beneficial use of biosolids. These factors include limited public acceptance especially with regard to odors, liability concerns of landowners, certain cost factors, and the type of crop grown. This section discusses these barriers as well as ways that these barriers might be overcome, such as through increasing public outreach efforts and ensuring the availability of diverse biosolids products for a variety of uses (e.g., both advanced treatment [such as composted] biosolids as well as less highly processed Class B biosolids products [to which site restrictions and use restrictions apply]).

5.2.1 Public Acceptance

Some public resistance to the beneficial use of biosolids persists based primarily on concerns about potential health, environmental, or nuisance impacts. The public's perceptions of biosolids treatment and application can affect whether a facility is built, where it is sited, and how it is operated. Although public perception is often not based on science and can be irrespective of the degree of risk to human health or the environment, it can present a significant deterrent to increased beneficial use. Understanding what the public concerns are can allow biosolids managers to address these concerns as part of their biosolids management program. Overcoming public resistance to the beneficial use of biosolids involves a combination of sensitivity to public perception issues, a framework within which the concerns can be addressed, and a willingness to address these issues through management practices and technologies, effective outreach programs, and active marketing of biosolids products.

The public's concerns can be addressed and alleviated in part by increasing their understanding of how advancements in biosolids technologies and regulations governing the use and disposal of biosolids have resulted in high-quality products that are safe and suitable for use. One very effective approach toward accomplishing public education is to assemble a biosolids "team" that includes representatives from all key community stakeholders including university or other scientists, water quality professionals, public health officials, agricultural groups and farmers, the environmental community, regulatory officials, and the media. Although some in the environmental community may oppose biosolids use, obtaining the involvement of an environmental group can result in a more successful effort. For example, consider the experience of existing groups that have addressed public concerns about biosolids, including the Information Sharing Group in New Jersey and New York, whose efforts included researching the use of biosolids in an ecologically sensitive area, and the Northwest Biosolids Management Association (NBMA), in which a member conservation organization, the Mountains to Sound Greenway Trust, conducts a highly successful public education campaign (Walker, 1998) (see the case study on King County, Washington, in Section 5.3 for more information on the NBMA).

In addition to implementing a good public education campaign, it appears that going beyond the requirements of the Part 503 Biosolids Rule (such as conducting additional site monitoring or using Class A biosolids), which is occurring in a number of locations, can increase the public's acceptance of biosolids use. It is important to note that a number of biosolids projects are currently being placed on hold until states and counties develop their own more stringent rules or ordinances for biosolids use.

Public concern also persists regarding the perceived lack of oversight of biosolids regulations. Successful oversight can be provided in part by incorporating an operation fee into a biosolids management program that is designated specifically for third-party inspectors who ensure compliance with the regulations. Also, the biosolids community is now working to develop an Environmental Management System (EMS) for biosolids that will encourage good management and community practices that go beyond basic compliance with the applicable federal, state, and local rules and will include third-party oversight. The EMS concept for biosolids helps generators, processors (e.g., composters), and others focus on critical control points. For example, a critical control point for odor is at the POTW, and proper management would involve analyzing how the biosolids are conditioned, thickened, dewatered, and stabilized at the POTW. In addition, conducting demonstration projects that illustrate good biosolids management and the benefits and safety of using biosolids may also improve public acceptance of biosolids use (Walker, 1998).

Odors

The potential for offensive odors can be a significant obstacle, if not the greatest obstacle, to increasing the beneficial use of biosolids. Not only do the odors themselves cause a public concern, but odors also trigger fears that 'foul-smelling' residues from municipalities and industry must be toxic and harmful. In some parts of the country, where rapid suburbanization of former farmland has occurred, biosolids application might no longer be used on the remaining farmland because proximity to residential areas makes actual or potential odor concerns unacceptable to the new neighbors. In other areas, treatment and good management practices can control most odor problems keeping them to a minimum; however, occasionally even the best run operations may emit offensive odors. In these instances, there are a number of odor-control methods, from biofilters to neutralizing solutions, that can help. The composting process may generally be able to reduce biosolids odors, although the composting process itself could generate offensive odors if not managed properly.

Considerable information is available on abating or controlling odors generated from composting or other biosolids use operations, and new methods are being developed. Odors can be controlled by treating malodorous biosolids with lime prior to shipping to an application site, minimizing anaerobic conditions, maximizing the ability of microbes to break down substances, injecting biosolids into the soil rather than spreading them on the land surface, and collecting, treating, and dispersing any odors that are formed (USDA, 1997; Walker, 1998). Mitigating odor problems is another opportunity for the successful implementation of an EMS where generators, processors, and recyclers of biosolids products will decrease the generation of odors in addition to minimizing other nuisances impacting public acceptance and perceived oversight. Thus, odor problems can be prevented or mitigated with technology, advanced planning, and/or good management practices.

Environmental and Health Concerns

Environmental and health concerns are often the major issues that biosolids managers must address. The public's concerns about biosolids often focus on infectious diseases, bioaerosols, water quality, and the introduction of pollutants into the environment. A large number of disease-causing bacteria, viruses, and parasites, including Salmonella and Shigella, are found in untreated wastewater and biosolids. To the extent that people are unaware of how thoroughly biosolids are treated to control pathogens, public concern over exposure to pathogens can impede beneficial use projects. Increasing the public's awareness of the regulatory requirements of the Part 503 Biosolids Rule for pathogen reduction can help mitigate this concern. Box 4 summarizes the two levels of pathogen reduction, other requirements, and typical uses of Class A and Class B biosolids. These requirements include treatment of the biosolids (e.g., through heat drying, composting, or other methods) to reduce pathogens to below detectable levels and reduce odor and vector attraction (Class A); in some cases, site restrictions are required that allow further pathogen destruction and reduce potential public exposure (Class B).

Box 4: Biosolids Classifications

The Part 503 Biosolids Rule classifies biosolids on their level of pathogen reduction.

Class A Biosolids undergo advanced treatment to reduce pathogen levels to below detectable levels. Heat drying, composting, and high-temperature aerobic digestion (described in Section 2.2) are treatment processes that typically achieve Class A pathogen reduction requirements. Class A biosolids, often sold in bags, can be beneficially used without pathogen-related restrictions at the site. If they also meet vector reduction requirements and Part 503 concentration limits for metals, Class A biosolids can be used as freely and for the same purposes as any other fertilizer or soil amendment product.

Class B Biosolids are treated to reduce pathogens to levels protective of human health and the environment, but not to undetectable levels. Thus, Class B biosolids require crop harvesting and site restrictions, which minimize the potential for human and animal contact until natural attenuation of pathogens has occurred. Class B biosolids cannot be sold or given away for use on sites such as lawns and home gardens, but can be used in bulk on agricultural and forest lands, reclamation sites, and other controlled sites, as long as all Part 503 vector, pollutant, and management practice requirements also are met.

Concerns also have been raised about the possible health effects associated with inhalation of airborne dust ("bioaerosols") originating from composting facilities. According to research published in *Compost Science & Utilization* (Millner, et al., 1994), bioaerosols (e.g., *Aspergillus fumigatus*) from composting do not impose any unique endangerment to the health and welfare of the general public. The report acknowledges, however, that further research into the occupational hazards of workers at composting sites is needed. Use of proper worker protection (e.g., dust masks or respirators) at composting sites during screening would reduce such risks considerably.

The Part 503 Biosolids Rule also provides numerous safeguards for protecting water quality (for example, when Class B biosolids are applied in bulk, Part 503 states that they cannot be applied less than 10 meters from any surface waters). Nevertheless, public concerns remain about the potential for biosolids to pollute water resources. As explained in EPA's technical support documents for Part 503 for land application and pathogen control (U.S. EPA, 1992a; U.S. EPA, 1992b), the potential for contaminants in land-applied biosolids, such as heavy metals, volatile and semivolatile organic compounds, pesticides, nutrients, PCBs, and pathogens, to reach surface water and ground water was extensively evaluated, and limits for metals were established that ensure protection of surface waters. (EPA's risk assessment showed that of all potential toxins, only metals were potentially present in biosolids at levels that might be of environmental concern.)

The limits set for metals in the Part 503 Biosolids Rule ensure that risks of contaminants entering surface or ground water will be minimal. Additionally, even at these minimal levels set for metals, composting binds the existing metals in the biosolids and prevents them from migrating to water resources, being absorbed by plants, or becoming bioavailable to humans (U.S. EPA, 1997a). Furthermore, under most circumstances, biosolids must be land applied only at rates that meet the nitrogen needs of a crop and minimize leaching of nitrogen to ground water, thus protecting ground water from possible nitrate contamination. Also, many states go beyond the Part 503 requirements in terms of management practices and setback requirements, and a few states have more stringent metal limits than those set in Part 503. Increasing public awareness about the low risk of contamination of ground water or surface water by nutrients, pathogens, or chemicals in biosolids and composted biosolids is an important component of a biosolids beneficial use program.

Public concerns also persist regarding the presence of pollutants and pathogens in biosolids that might find their way to humans through plant uptake, direct contact, and animal ingestion. Although considerable independent research exists to demonstrate that the risks to humans are negligible, the public might perceive higher risks due to the origin of biosolids and past management practices (USDA, 1997). The Part 503 Biosolids Rule was designed specifically to protect human health and the environment from these types of risks. EPA's technical support document for the rule presents the data, assumptions, and methodologies EPA used to set limits on pollutants in land applied biosolids (U.S. EPA, 1992a). The Agency investigated 14 pathways of exposure including plant and animal uptake of metals with subsequent ingestion by humans and direct ingestion of biosolids by children. The limits set in Part 503 are protective of human health and the environment under all likely ways that plants, animals, or humans can be exposed to pollutants in biosolids.

Informative outreach programs that deal directly with health and environmental issues and that present the ways in which the Part 503 Biosolids Rule and state pollutant limits and management practices minimize these risks can help to increase public acceptance, as demonstrated by the example programs highlighted in Section 5.3. A useful document for reference on the protection provided by the Part 503 rule is EPA's *Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule* (U.S. EPA, 1995b).

5.2.2 Liability Concerns

Property owners, lending institutions, and others involved in biosolids land application have expressed concerns about liability under laws such as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 and nuisance lawsuits. Adherence to the requirements of the Part 503 Biosolids Rule, however, addresses these concerns. Persons who land apply and beneficially use biosolids in accordance with Part 503 are not subject to CERCLA liability or other federal enforcement actions (Walker and Albee, 1994). The pollutant limits and management practices required in the Part 503 rule for land application of biosolids ensure that land-applied biosolids are nonhazardous. Also, the records maintained as part of meeting the Part 503 Biosolids Rule requirements provide evidence that the biosolids placed on a site are nonhazardous.

5.2.3 Costs

The Part 503 Biosolids Rule regulates numerous biosolids management options, but communities must decide which options are most appropriate and cost-effective given their circumstances. Data developed for the proposed Part 503 rule (*Federal Register,* Vol. 54, No. 23, pp. 5476-5902, February 6, 1989) indicated that the least expensive management options were surface disposal and crop application. (Surface disposal has become significantly less prevalent because of the additional costs imposed by the Part 503 Biosolids Rule; crop application, prior to the promulgation of either the municipal solid waste landfill regulations or Part 503, was roughly equal to an assumed average cost for landfilling [including transportation].) Land application costs (due to suburbanization and possible increases in hauling distances to agricultural land in some areas) may have increased in the intervening years. Monofilling of biosolids was roughly 20 percent more expensive than either surface disposal or land application on average and most likely is still more expensive following the implementation of Part 503. Furthermore, landfilling, since the municipal solid waste landfill regulations came into effect, has generally increased in cost disproportionately in comparison to these other methods, although landfill costs in some areas are very inexpensive due to the construction of increasingly large landfills, sometimes called “megafills.”

Cost information for different types of composting processes, researched by *BioCycle* magazine is shown in Table 5-1, including capital and operating and maintenance costs for different types of composting methods. The wide variations in costs are due to vast differences in size from the smallest to largest facilities. Small facilities will generally incur the smallest capital costs, but can incur relatively higher operation and maintenance costs on a per-ton basis. A high cost per ton is typical of facilities that compost only a few tons per year.

Table 5-1
Biosolids Composting Costs[a]
(1997 data from 100 composting facilities)

Type of Composting Method	Capital Costs[b]	Operation and Maintenance Costs
Aerated Static Pile	$36,000 - $20 million	$12 - $500/dry ton
In-Vessel	$850,000 - $33 million	$18.24 - $540/dry ton
Windrow	$50,000 - $8 million	$2.15 - $245/dry ton
Aerated Windrow	$450,000[c]	$50 - $325/ton
Static Pile	not reported	$25 - $165/ton

Source: Goldstein and Block, 1997.
[a]Does not reflect revenue generated from the sale of composted products.
[b]Costs reported by operations are estimates in many cases. The wide range reflects management differences at sites, as well as what each facility factors into the operating costs.
[c]Only one facility reported a capital cost.

Based on the research, distribution and marketing of biosolids products (e.g., composting operations) was, on average, more than three times the cost of the least expensive options, although this does not take into account revenue from the sale of the compost, which will offset some of these costs (100 composting facilities reported revenues of from $1 to $35 per cubic yard, according to Goldstein and Block, 1997). Also, with reductions in nearby agricultural land in some areas and the fact that many users of compost provide their own transportation, the difference in cost between composted biosolids and land application of less highly processed biosolids is likely to be decreasing. Furthermore, there are considerable economies of scale involved in composting, and some communities might find that composting operations using both biosolids and organic MSW materials, especially yard trimmings, might become more economical on a cost-per-ton basis than disposing of either waste individually. Incineration and land reclamation were, prior to 1989 and most likely still are, the most expensive options on a unit cost basis. The cost of land reclamation as presented in the *Federal Register,* however, includes the cost of the reclamation process itself. If one compares the cost of reclamation with biosolids to the cost of reclamation without biosolids (that is, using soils purchased or obtained from other locations), the cost of reclamation using biosolids could be relatively much lower, and might even represent a cost savings. In land reclamation, it is the expense of landshaping using costly earth-moving equipment, and not the biosolids use, that drives costs. Also, three times the amount of biosolids can be applied for land reclamation as for land spreading at the agronomic rate for crop growth. Furthermore, the costs of land reclamation reported in the *Federal Register* also do not take into consideration the difference between the costs of unused, unproductive land and reclaimed productive land through enrichment by biosolids or composted biosolids.

Although land application of biosolids is one of the least-cost management options, the cost to municipalities or farmers of applying biosolids, monitoring, recordkeeping, and meeting the management practices of federal, state, and local regulatory agencies can impede biosolids use. Although biosolids are valuable to farmers as a soil amendment, and some or all of these costs can be incurred by the contractor or POTW, the availability of low-cost commercial fertilizers may limit farmers' willingness to pay for biosolids (National Research Council, 1996). In some municipalities, however, such as Seattle, Washington, and Madison, Wisconsin, users pay for their biosolids. In others, POTW managers can promote biosolids use by setting up demonstration projects using biosolids, assisting in the recordkeeping tasks, and covering the cost of applying the biosolids. In several localities, marketing of biosolids for beneficial use is not a problem at all; in Madison, Wisconsin, for example, as well as other areas, the demand for biosolids as a soil amendment exceeds the local supply (see Section 5.3).

In comparison, composting is considerably more expensive than land application, based on EPA's Regulatory Impact Analysis (RIA) for the proposed Part 503 Biosolids Rule (U.S. EPA, 1989), although, as discussed above, the cost differential may be shrinking in some areas. The cost of composting operations can affect whether this particular beneficial use option is chosen, but the desirability of the composted product and the potential market for a sellable product that is proven to be safe can offset some of this cost. In Columbus, Ohio, for example, the city's compost product, which is sold to the general public as a soil amendment, has been so successful that on various occasions demand has far exceeded supply. The case studies presented in Section 5.3 illustrate the demand for biosolids and the process that can be used to market composted and other types of biosolids.

Transportation of biosolids is also a substantial cost category for POTWs, and these costs can have the most significant effect on the total costs of land application. Furthermore, the distance to land application sites is increasing as available land closer to the point of generation becomes more developed (thus requiring biosolids to be hauled farther). Reducing biosolids volume through thickening, dewatering, conditioning, and drying can reduce these costs. Preparation and long-distance shipping of pelletized biosolids, for example, generally can be less expensive than for nonpelletized biosolids because the reduced water weight results in lower transport costs (communication with Massachusetts Water Resources Authority, February, 1998). Transportation costs also can be greatly reduced by finding local markets for biosolids compost.

5.2.4 Crop Considerations

In a number of locations, fiber crops are being replaced with food crops. When Class B biosolids are applied to land where food crops are raised, waiting periods before harvesting are imposed, which can reduce the usefulness of Class B biosolids. Municipalities applying biosolids in these areas might need to have their treatment plants change their treatment process to produce Class A biosolids (i.e., nondetectable pathogen levels), which require no waiting period before crop harvest, to encourage farmers to continue to use biosolids; transport biosolids farther to land apply; or landfill biosolids instead of land apply them. These trends highlight a need for municipalities to: 1) continue identifying new locations suitable for land application of Class B biosolids or 2) consider adding Class A treatment processes.

5.3 Examples of Beneficial Use

The following five examples illustrate how some communities have successfully addressed the management and beneficial use of biosolids, often in cooperation with municipal solid waste operations. Each of the programs stresses the importance of education and outreach to obtain public acceptance. The programs also rely on a variety of disposal and use options, which ensures that biosolids will be properly managed even in the event that any one option is no longer viable. Some of the case studies were summarized from applications submitted to EPA's Office of Water for its annual Biosolids Beneficial Use Awards Program for Operating Projects, Technology Development, Research, and Public Acceptance. These summaries were updated in 1998 with information provided by key operating personnel in the municipalities.

5.3.1 King County, Washington

King County operates a highly successful biosolids management program that results in the beneficial use of all biosolids produced at the West Point Treatment Plant in Seattle and the East Division Treatment Plant in Renton. In 1996, these two wastewater treatment plants, with secondary treatment capabilities, processed a combined 100,000 wet tons (20,000 dry tons) of biosolids, which were eventually digested anaerobically, dewatered using a centrifuge or a belt-filter press, and land applied. In 1995, one of the biosolids products originating from these two plants, a Class B biosolids cake, was used for agricultural land fertilizer and forest applications (such as reclaiming and regreening scars left from logging roads). A portion of the biosolids is composted by a private contractor and marketed under the name GroCo® as a general compost for a variety of applications including those in Seattle parks.

King County receives revenues from its biosolids cake product provided to farmers and forest owners at $15 to $25 per acre and $35 to $60 per acre, respectively. These prices reflect what each buyer would pay for equivalent chemical fertilizers. In fact, land application of King County's biosolids cake product, accounting for 90 percent of the county's biosolids, has proven to be so effective as a soil fertilizer or amendment that current demand significantly exceeds the supply. The county also receives $5 per dry ton from the contractor who composts and markets the other 10 percent of the county's biosolids. In 1995, King County received over $100,000 in revenues from selling biosolids, which helps offset the cost of hauling biosolids from the treatment plant to the contractor. King County also pays to have the biosolids land applied. These hauling and application costs are less expensive than disposal in a landfill.

In the early 1980s, the King County biosolids management program suffered a series of setbacks due to organized public resistance to land purchases for long-term biosolids cake application projects. As a result of the public's resistance, most land application projects receiving treated biosolids were halted. The King County Council then required that the staff of the Biosolids Management Program be accountable to the council and the public regarding the issuance of permits and informing the public of projects. Augmenting this shift in accountability from private contractors to the county staff was the formation of the Northwest Biosolids Management Association (NBMA), an association of 150 municipal biosolids agencies and private firms that work together to share management strategies and initiate research and public education programs. Together, these developments helped improve public acceptance and provided information to regulatory agencies, elected officials, and the public.

The current success of King County's biosolids management program is mainly due to the county's extensive outreach and education efforts through NBMA, the program's excellent performance record (i.e., no contamination events or regulatory compliance issues), and the development of an efficient and reliable biosolids and biosolids compost market.

Public trust and interest has been solidified through the Mountains to Sound Greenway Biosolids Forestry Program, a comprehensive effort to restore and protect logged-over mountain slopes and road scars in the I-90 corridor of Washington State by the Washington Department of Natural Resources, Weyerhaeuser Company, University of Washington, King County, and the Mountains to Sound Greenway Trust. The Weyerhaeuser Company will increase its use of King County biosolids from 2,000 dry tons to 5,000 dry tons per year to stimulate accelerated vegetative growth in this region. The Greenway Trust, a respected conservation organization, promotes the use of biosolids, conducts public education on biosolids recycling and environmental sustainability, and manages the compost land application program. This project represents a new way of doing business for wastewater treatment utilities, offers a creative way to reduce ratepayer costs, and helps the public realize the value of the services and products created by wastewater treatment.

5.3.2 Los Angeles County, California, Sanitation Districts

Use of biosolids in Los Angeles County began in 1928 with a contract between a fertilizer supply company and the Joint Water Pollution Control Plant (JWPCP) in Carson, California, to distribute dewatered, digested biosolids cake from the plant. Since that time, the County Sanitation Districts of Los Angeles County (CSDLAC) system, which operates the JWPCP, has grown to seven POTWs linked by a common sewer system serving 5 million people in Los Angeles County and treating 500 million gallons per day (MGD) of wastewater.

Residual solids from six upstream treatment plants with a combined flow of 170 MGD are returned to the sewer system for centralized processing at the JWPCP, where an additional 330 MGD of wastewater are also treated. All solids are anaerobically digested at 35° C (96° F) for 20 days and dewatered using scroll centrifuges to 26 percent total solids. CSDLAC has adopted a strict pretreatment program that helps ensure all biosolids meet the Part 503 requirements for quality. In 1997, the JWPCP generated 119,000 dry tons of Class B biosolids that meet the Part 503 Biosolids Rule high-quality pollutant concentration limits.

JWPCP operation and maintenance costs in 1997 were approximately $50 million. These costs would have been considerably higher if not for various cost saving measures implemented on site, such as using digester gas to produce steam for heating, fuel pump engines, and generate electrical power. These measures allowed JWPCP to be energy self-sufficient and save nearly $5 million in 1997. Another cost saving measure has been to enhance the dewatering performance of the centrifuges, resulting in a major reduction in cake production and a savings of several million dollars.

Because of the tremendous volume served by JWPCP, the county developed various ways to manage biosolids in the last several years. This diversity ensures that no one contractor, locality, or management practice is relied on so heavily that its absence in the program would threaten the CSDLAC's ability to handle its biosolids. The program currently consists of four different management practices in five counties at seven independent sites that are located up to 200 miles from JWPCP. The four biosolids management practices include: land application, which accounts for 76 percent of the system's biosolids; injection into a cement kiln, which accounts for another 12 percent of the biosolids and helps reduce the levels of nitrogen oxide (NO_X) air emissions from the cement making process; composting, which has been moved off site to two privately operated facilities; and landfilling, which accounts for approximately 12 percent of the system's biosolids. CSDLAC is in an advantageous position because it owns and operates a sanitary landfill. The landfill adds flexibility to the entire biosolids system by providing disposal capacity when conditions might be unsuitable for land application.

Diversity thrives on a continuous evaluation of new alternatives. The CSDLAC has a long history of biosolids processing research and development. An example is the construction of a demonstration (2 dry tons per day) in-vessel composting unit combined with a CSDLAC-patented air pollution control system that produces virtually no odors or pollutant emissions. CSDLAC also plays an active role in local and statewide organizations that promote biosolids use and guide the development of new regulations that address the public's needs while encouraging beneficial use.

5.3.3 City of Austin, Texas

The City of Austin Water and Wastewater Utility has operated a successful biosolids recycling program since 1986. Austin's biosolids recycling program receives approximately 500,000 gallons, or 50 dry tons, of biosolids daily from the city's three wastewater treatment plants. The biosolids are mixed in a flow equalization basin and thickened to 6 to 8 percent solids content before being anaerobically digested. After anaerobic digestion, the biosolids are dried in a mechanical dewatering unit or directed to one of five, 5-acre, open-air concrete drying basins and dried to a solids concentration of 15 to 25 percent.

About 55 percent of the dried biosolids are mixed with bulking agents (including yard and tree trimmings), windrow composted, and sold as Dillo Dirt® to the general public through registered vendors. This compost product is used as a soil conditioner for residential lawns and flower gardens and complies with Part 503 Biosolids Rule requirements for Class A pathogen and vector attraction reduction. Approximately 20,000 cubic yards of Dillo Dirt® are produced annually, with 95 percent sold for $7 per cubic yard to registered vendors including landscapers, nurseries, and garden centers. The remaining 5 percent is given away to other city departments and local nonprofit organizations. Due to the success of marketing efforts, the demand for Dillo Dirt® often exceeds the supply.

The remaining 45 percent of dewatered biosolids cake meets Part 503 requirements for Class B pathogen and vector attraction reduction and is land applied to a farm where hay and pecans are grown.

The Austin program enjoys strong public acceptance resulting from public education and outreach efforts, tours, positive media coverage, and strict adherence to permit requirements. The city has demonstrated the benefits of biosolids-based soil amendments in various local projects. Also, in a jointeffort with the Texas Department of Transportation, the city has demonstrated the benefits of using compost to increase vegetation along Texas highway roadsides.

The annual operating budget for the Hornsby Bend Biosolids Management Plant, the city's centralized biosolids treatment and use facility serving a population of 550,000, is approximately $3 million. Revenues generated through the sale of Dillo Dirt® and the land application of dried biosolids exceeds $150,000 annually. In addition, all of the city's yard and tree trimmings are recycled by the program, resulting in approximately $500,000 in avoided landfill disposal costs per year.

Austin's biosolids recycling program has prospered through many challenges, including the lack of usable equipment and bulking agents for compost and the lack of space for a compost pad. A unique and successful partnership between the multiple city departments, including solid waste services, electric utility, parks and recreation, and water and wastewater, has allowed the program to expand by sharing costs for additional equipment and personnel.

5.3.4 Columbus, Ohio

Several years ago, when federal funding for new incinerators was unavailable, EPA encouraged the city of Columbus to establish a biosolids beneficial use program. In response, the Columbus Department of Public Utilities established a biosolids recycling program through three city-owned facilities: Columbus Compost Facility, Southerly Wastewater Treatment Plant, and the Jackson Pike Wastewater Treatment Plant.

The Jackson Pike facility handled 78 MGD of wastewater and produced approximately 15,400 dry tons of biosolids in 1997. Biosolids are stabilized in an anaerobic digester on site with a 58 percent volatile solids reduction. A portion of the biosolids from the Jackson Pike Plant, locally distributed as Bio-Rich®, is applied to agricultural areas using a subsurface injection process. The remainder of the biosolids is incinerated. Biosolids produced by the Jackson Pike Plant are categorized as Class B biosolids products under Part 503.

In 1997, the Southerly facility treated 82 MGD of wastewater and produced 28,400 dry tons of biosolids, of which 3.8 percent was stabilized using alkaline treatment on site, 30.5 percent was composted, 8 percent was landfilled, and the remainder was incinerated during production of “Flume Sand.” A product of incineration, Flume Sand is a fine red sand that absorbs water more readily, costs less, and is less abrasive than natural sand. It is used throughout the Columbus area as an athletic-field amendment. Sales and distribution of Flume Sand were suspended in June 1997 once the pilot project came to an end, because the city failed to acquire state approval to finalize the program due to a lack of state environmental standards. The city is currently preparing a plan for distribution of Flume Sand that will be submitted to the state for approval.

A portion of the biosolids is diverted from the dewatering centrifuges to lime stabilization, then land applied by subsurface injection at 6 percent total solids. The remaining biosolids and raw primary biosolids are blended and dewatered to 20 percent total solids for composting or 24 percent total solids for incineration. In the composting operation, the dewatered biosolids cake is composted using aerated static piles. It is then placed in windrows to cure for 60 days, producing a Class A product according to the Part 503 Biosolids Rule. The compost is sold in bulk and bags as Com-Til® to the general public for use as a soil amendment. From 1994 to 1997, the city of Columbus averaged 9,800 dry tons of Com-Til® sales per year.

The city’s biosolids management program has proved to be cost-effective and adaptable. From 1994 through 1996, Flume Sand use resulted in $92,000 per year in avoided landfill disposal costs and generated $18,190 per year in revenues. During that same period, Com-Til® also generated $263,250 per year in additional revenues. Com-Til® has been so successful that on various occasions the product has been sold out.

The city's biosolids recycling program is well accepted throughout the community, and there is high demand for all the biosolids products. This situation is primarily due to the various marketing programs, education, and outreach efforts of the city's Department of Public Utilities. Educational programs have focused on the environmental and neighbor-friendly aspects of the various biosolids products. The program, however, initially had to overcome some obstacles. Problems with excessive biosolids stockpiling on farmland, low market demand for biosolids products, odor, and poor public perception (stemming from potential contamination events brought about by runoff) were encountered. These problems were solved by diverting a large portion of the biosolids to land application without centrifuge dewatering. The biosolids, at 6 percent solids, were lime stabilized and land applied by injection, which reduced odors (when compared to surface-applied cake biosolids), reduced concerns about runoff, and eliminated field stockpile problems. Diverting a large portion of biosolids from the dewatering process also helped improve the performance of the centrifuges and, indirectly, the incinerator, as a result of the higher solids content of the final dewatered cake. Furthermore, by increasing the total solids content of the biosolids, the centrifuges also reduced compost material handling costs.

5.3.5 Charlottesville, Virginia

The Rivanna Water and Sewer Authority oversees the operation of the Moores Creek Advanced Wastewater Treatment Plant in Charlottesville, Virginia, which is located approximately 120 miles southwest of Washington, DC. The plant began operating in 1981 and today serves a population of 75,000 (26,000 connections) from the city of Charlottesville and portions of surrounding Albemarle County. The plant treats 11 MGD of wastewater and has a design capacity of 15 MGD. The plant is equipped with primary, secondary, and tertiary treatment systems, which produce a total of approximately 7,500 cubic yards of dewatered biosolids per year on average. Wanting to be on the cutting edge of wastewater management, the city of Charlottesville began to look into ways it could use its biosolids beneficially while saving landfill disposal costs. As a result, the Moores plant began composting its biosolids in 1984. Today, the facility produces and sells 5,700 cubic yards of compost annually for use as a soil amendment. The remaining 1,500 cubic yards (25 percent) of biosolids is land-applied or used as landfill cover. The plant hopes to begin composting 100 percent of its biosolids in the future.

Once filtered from wastewater, the solids are anaerobically digested. Methane gas, approximately 95,000 cubic feet per day produced by the digestion process, is used to operate gas engines that run the blowers providing air for the aeration basins used in the secondary and tertiary treatment stages. Water heated using waste heat from these engines also helps heat the digesters and some of the buildings at the plant. After digestion, the solids are dewatered in a diaphragm filter press (plate-and-frame filter press), which removes about 65 percent of the water. From there, the biosolids are ready for use in the composting process.

The biosolids are transported to an adjoining compost area on the plant premises. Biosolids from the wastewater treatment plant are mixed with wood chips at a ratio of three parts wood chips to one part biosolids. The facility annually uses 4,000 cubic yards of wood chips that come from chipped pallets purchased from a pallet company located in Richmond, Virginia, for $5 per cubic yard ($18 to $22 per ton). The biosolids/wood chip mixture is placed on a bed of fresh wood chips covering an asphalt pad in a series of static piles protected from the weather. The compost temperature is monitored and maintained between 55° C and 77° C (131° F and 170° F) for 5 days. The temperature probes are then removed and the piles are left to compost for an additional 10 days, for a total of 15 days to complete the active composting process. The compost is then cured for 1 month and is tested for salmonella and metals on a quarterly basis.

The Moores Creek plant's compost is made available for sale once a month to the public, selling for $12 per cubic yard in bulk and $15 per cubic yard for small purchases. Some compost is also manually bagged and sold for $3.50 per 40-pound bag. It is sold to individuals, nurseries, farmers, and local park and recreation departments for use on lawns, flowers, house plants, trees, shrubs, and vegetables.

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Appendix

Biosolids Generation, Use, and Disposal Methodology and Results

A.1 Introduction

Biosolids generation, use, and disposal estimates made in this report in Section Three and projections of generation, use, and disposal in Section Four are based on a number of information sources. Estimates of biosolids generation were based primarily on the 1988 National Sewage Sludge Survey (NSSS) and the 1984 through 1996 Needs Surveys, as discussed in detail in Section A.2 and A.4 of this appendix. Several other sources of information on generation rates and use and disposal methods were also investigated, such as the Water Environment Federation's (WEF) 1997 report and Robert Bastian's 1997 paper, which provide data estimates on biosolids generation, use, and disposal in 1995 and 1996, respectively. *BioCycle* (1991, 1997, and 1998) also provides information on generation and use and disposal methods. The biosolids generation estimates from the WEF report or Bastian (1997) were considered, but this report also made additional estimates as described in this appendix to verify the results of these other studies. This appendix discusses the major data sources used for estimating generation, use, and disposal of biosolids; the strengths and weaknesses of the data sources; and the methodologies and results of this analysis.

In 1988, EPA conducted the NSSS, a survey of a random sample of 479 publicly owned treatment works (POTWs) to support the development of the Part 503 Biosolids Rule. The survey produced a statistically valid estimate of the amounts of biosolids used or disposed of by POTWs using at least secondary wastewater treatment processes. At that time, the number of POTWs using at least secondary wastewater treatment totaled approximately 11,400. The survey was stratified on the basis of POTW size (amount of wastewater processed daily) and principal use or disposal method. The survey also collected data on pollutant concentrations in biosolids, from which EPA could determine whether biosolids would meet the criteria being developed under the Part 503 Biosolids

Rule. At the time, EPA considered the NSSS estimate of the amount of biosolids used or disposed of as the most accurate estimate to date. The NSSS, however, is no longer current and also does not provide estimates of biosolids generation by POTWs using primary wastewater treatment processes[12] or by privately or federally owned treatment works. Most importantly, the NSSS cannot provide an estimate of current practices because the survey was undertaken before the Part 503 Biosolids Rule was finalized. The Part 503 rule has had an impact on POTWs' choices of use or disposal methods, since it generally was written to encourage POTWs to choose beneficial use rather than disposal if the biosolids were of sufficiently high quality (U.S. EPA, 1993a).

The WEF (1997) report, which was conducted in cooperation with the Association of Metropolitan Sewer Agencies (AMSA) using an EPA grant, is an inventory of biosolids generation, beneficial use, and disposal practices for 1995. WEF surveyed 162 AMSA members and received 117 responses. Twenty-five states and federal regulators also responded to the survey. Additionally, the report presented information on biosolids beneficial use practices, appropriate regulations, and attitudes. Although the information in this report is current and represents half the wastewater flow in this country, the survey primarily captured data from AMSA members, which tend to be the largest POTWs. The POTWs associated with the other half of the flow might not operate like the POTWs represented by the WEF data, although the addition of data from other sources might have helped reduce the large-POTW bias in the data. Despite possible drawbacks, the WEF data does provide breakdowns of biosolids quantities by use and disposal methods that can easily be adapted to the categories of use and disposal methods used in this report.

Data from Bastian (1997) are current for 1996. That paper, published in *European Water Pollution Control* (March 1997) presented results of a survey of state regulators who were asked for 1996 data on total biosolids production and the percentage of biosolids used or disposed of by land application, surface disposal, incineration, and other means. The paper also describes changes in biosolids management and treatment and discusses obstacles to biosolids management, such as public acceptance and liability issues. Unless the state is authorized as the permitting authority, however, it might not have detailed records of biosolids generation, use, and disposal that would best support a national estimate. Furthermore, some states do not have easy access to permit information (i.e., in database form) from which viable aggregate data might be drawn. Finally, much of the more detailed data are kept primarily at the POTW level (particularly among the smaller POTWs, which are not required to report any of their recordkeeping data to the states unless specifically requested or unless their biosolids quality triggers specific reporting requirements). Therefore, although some states have excellent data from which to compile state estimates of biosolids generation, use, and disposal, other states may only be able to estimate roughly the amounts of biosolids generated, used, or disposed of. Additionally, the WEF report further refines the breakdown of use and disposal

[12]For purposes of this appendix, the term primary processes means those considered less than secondary and the term secondary processes means those considered at least secondary.

categories, originally presented in Bastian (1997), in a way that is effective for the purposes of this report.

Researchers at *BioCycle,* a journal that covers recycling and management of biosolids and other organic wastes, surveyed state regulators regarding biosolids generation and management in 1989, 1996, and 1998. The surveys provide a state-by-state breakdown of management practices according to land application, composting, lime stabilization, heat drying or pelletizing, landfilling, incineration, or surface disposal. The journal also conducts an annual survey of biosolids composting operations. Again, because these are state data, the information can vary from sketchy to excellent, depending on the level of data collection and management at the state level. As discussed below, the most recent survey (1997 data) provides data on both total quantities of biosolids generated (in dry tons) and use and disposal practices for 34 states (*BioCycle,* 1998). Because only 34 states with adequate data for the purposes of this report are represented in the data, any conclusions drawn from these data may be somewhat limited.

All these sources of information on generation, use, and disposal of biosolids have their relative strengths and weaknesses. Ultimately, the choice was made to estimate biosolids generation using the NSSS to provide one more data point for consideration in addition to analyzing data from the 1997 WEF report and Bastian (1997) and to use the 1997 WEF report for the distribution of use and disposal methods. The *BioCycle* (1998) data and the NSSS were also used as additional support for the estimates of use and disposal methods. As the results show later in this appendix, the biosolids generation estimates from the WEF (1997) report, Bastian (1997), and this report are remarkably similar. We estimate that 6.7 million U.S. dry tons of biosolids were generated for use or disposal in 1996 (both 1996 and 1998 estimates are made in this report). Our estimate falls between the 1995 WEF estimate of 6.4 million dry tons and the 1996 Bastian (1997) estimate of 6.9 million U.S. dry tons. This estimate is used in this report for biosolids generated by POTWs practicing secondary or above wastewater treatment (the major source of biosolids in this country), along with additional information from other sources about primary treatment biosolids and those generated by privately and federally owned facilities (U.S. EPA, 1993a). This report uses the 1997 WEF study primarily as the basis for determining use and disposal practices in 1998, because the combined data from POTWs and states are likely to be more accurate than data strictly from the states alone. The WEF data were also chosen because of how the use and disposal categories are broken out.

A.2 Estimate of Biosolids Generation in 1998

This section describes our estimate of the quantities of biosolids generated in 1996 and then further estimates the quantities generated in 1998. These estimates are primarily based on the 1988 NSSS (results of which are reported in the Regulatory Impact Analysis (RIA) for the Part 503 Biosolids Rule [U.S. EPA, 1993a]) and the 1988 through 1996 Needs Surveys.[13] The NSSS does not address biosolids generation at POTWs using only primary treatment processes or biosolids generation at privately or federally owned treatment works, therefore, additional information was incorporated from the RIA and the Needs Surveys to estimate these quantities. To determine quantities of biosolids generated by POTWs using primary treatment processes, this report used an estimate of primary biosolids generation from the RIA (U.S. EPA, 1993a), which also was based on the 1988 Needs Survey. For POTWs using at least secondary treatment processes, this report used the NSSS and the Needs Surveys. We estimated privately and federally owned treatment works biosolids quantities using information developed in the RIA (U.S. EPA, 1993a). This stratification also was necessary to account for differences in biosolids generation rates at POTWs using either primary or secondary treatment processes, because primary processes can generate different amounts of biosolids per gallon of wastewater processed than secondary processes. The following discussion shows the development of an estimate of biosolids generation at POTWs, then follows with the development of an estimate of biosolids generation at privately and federally owned treatment works.

A.2.1 Estimate of 1998 Biosolids Generation at POTWs

Methodology

This report begins with an estimate of 1996 biosolids generation because 1996 is the most recent year for which data on total U.S. wastewater flow is available. The 1998 estimate is based on a projection from this 1996 base year.

The key assumption in this report for first estimating 1996 biosolids generation at POTWs is that once biosolids quantities are split between primary and secondary processes, the quantity of biosolids generated per gallon of wastewater treated at POTWs would not be substantially different in 1996 than it was in 1988.[14] Two Biosolids Generation Factors (BGFs), therefore, were created for estimating biosolids quantities resulting from each process, one for primary treatment and one for secondary and above. Each of the BGFs ($BGF_{primary}$ and $BGF_{secondary}$) is equal to the biosolids estimated to be generated by each treat-

[13]The 1984 and 1986 Needs Surveys also are used to identify trends in wastewater flow over time later in this appendix.

[14]Tertiary processes create additional biosolids per gallon of wastewater treated than either primary or secondary processes, and to the extent that wastewater going to tertiary treatment processes has increased since 1988, this approach could slightly underestimate biosolids generation rates. This underestimation was not corrected because summary data for the NSSS did not distinguish between biosolids generated in secondary treatment processes and those generated in tertiary treatment processes. The amount of wastewater going to tertiary treatment is, however, relatively small compared to that going to secondary treatment. Furthermore, biosolids generation might be slightly overstated (particularly for projections made later in this section) because dewatering processes are changing from ferric and lime processes to polymer processes, which reduce the volume of biosolids generated. Also, with bans on phosphates in detergents, fewer chemicals are needed for removing phosphates from wastewater, leading to further reductions in biosolids volume.

ment group in 1988 divided by the 1988 annual flow of wastewater treated by each treatment group. The formula below illustrates an example of this calculation:

$$\frac{\text{Biosolids Generated in 1988 Primary Processes (U.S. dry tons)}}{\text{Total 1988 Annual Primary Wastewater Flow (MGD)}} = BGF_{primary} \quad \textbf{(1)}$$

For this calculation, estimates of primary and secondary biosolids generation in 1988 were obtained from the RIA supporting the Part 503 Biosolids Rule (U.S. EPA, 1993a). For POTWs using secondary processes, the estimates of biosolids disposal and use from the 1988 NSSS (as reported in U.S. EPA, 1993a) were used to represent the amount of biosolids generated from secondary and above treatment operations.[15] The 1988 NSSS data were not used to estimate primary treatment process biosolids because the survey did not gather data on biosolids generated exclusively from primary processes. To identify quantities of biosolids generated from primary processes in 1988, the estimate of primary biosolids amounts that was developed in the RIA (U.S. EPA, 1993a) was used. This estimate was based on information obtained from the 1988 Needs Survey and engineering estimates.

Annual wastewater flow numbers associated with primary and secondary treatment were then obtained. The amount of 1988 annual flow for each treatment group (both primary and secondary) was taken directly from the 1988 Needs Survey. The 1996 Needs Survey data did not distinguish the flow rate by level of wastewater treatment process, however. We assumed that the flow for each treatment group was proportionate to the total population served for each treatment level reported in 1996.[16] For example:

$$\frac{\text{Population Served by Primary Treatment}}{\text{Total Population Served}} = \text{Percent of Total Flow Attributable to Primary Treatment} \quad \textbf{(2)}$$

and

$$\frac{\text{Population Served by Secondary Treatment}}{\text{Total Population Served}} = \text{Percent of Total Flow Attributable to Secondary Treatment} \quad \textbf{(3)}$$

[15]Biosolids can be generated in one year and used or disposed of in another year. It is assumed that the NSSS estimate of use or disposal in 1988 is roughly equivalent to generation, since some biosolids that were used or disposed of in 1988 were generated in previous years, whereas some biosolids that were generated in 1988 were not used or disposed of until later years. Although the NSSS did ask for data on generation, this information did not appear to be presented in any summary document reviewed. NSSS data on biosolids generation might have been of limited accuracy, since respondents with treatment lagoons who did not dispose of biosolids in 1988 would have needed to estimate generation rates.

[16]In making this calculation, the 1996 Needs Survey treatment levels were collapsed into two groups, primary treatment and secondary treatment. The primary treatment group is the same as the "less than secondary treatment" category, and the at-least-secondary treatment category includes the "secondary," "tertiary," and "no discharge" categories.

The percentages of population served for each treatment group in 1996 were applied to the total 1996 flow to estimate the flow attributable to POTWs in each treatment category. The applicable BGFs were then multiplied by the estimated 1996 flow for each treatment group (primary and secondary). For example:

$$BGF_{Primary} \times \text{Total 1996 Annual Flow for Primary Treatment (MGD)} = \text{Biosolids Generated in 1996 from Primary Flow (U.S. dry tons)} \quad (4)$$

and

$$BGF_{Secondary} \times \text{Total 1996 Annual Flow for Secondary Treatment (MGD)} = \text{Biosolids Generated in 1996 from Secondary Flow (U.S. dry tons)} \quad (5)$$

These results provided an estimate of the quantity of biosolids generated in 1996 for both the primary and the secondary treatment groups, the sum of which gave the total biosolids (in U.S. dry tons) generated by POTWs in 1996.

The estimate for 1996 was extrapolated to 1998 on the basis of an analysis presented in Section A.4. As Section A.4 discusses, primary treatment wastewater has been declining on average about 4 percent per year, and secondary and above treatment wastewater has been increasing on average about 2 percent per year. These increases and decreases are incorporated into projections of wastewater flow in those two treatment categories to derive estimates of biosolids generation in 1998.

Results[17]

As shown in Table A-1, we estimate (using Equation 1) that the $BGF_{primary}$ is 203. The $BGF_{secondary}$ is 206.[18] We also estimate that, in 1996, primary flow was 2,900 MGD and secondary flow was 29,200 MGD using Equations 2 and 3 (see Table A-2). These flow numbers and the BGFs calculated in Table A-1 are

[17]Throughout the tables in this appendix, totals might not appear to compute exactly because of rounding.

[18]Both factors fall within the expected ranges of biosolids generation from wastewater treatment processes, although generally one might expect the difference between $BGF_{primary}$ and $BGF_{secondary}$ to be somewhat greater because of the ability of secondary processes to remove additional pollutants from wastewater. There are several reasons for this result, however. The primary reason is that many POTWs with secondary wastewater treatment also treat their biosolids in biosolids treatment processes such as digesters that can dramatically reduce (by up to 90 percent in some cases) the volume of biosolids initially generated in the wastewater treatment process. Thus, the $BGF_{secondary}$ factor is associated with the ultimate, not the initial, biosolids volume generated. Biosolids generated by POTWs that use only primary treatment are much less likely to be treated in costly biosolids treatment processes that result in large volume reductions. Another major reason is that $BGF_{primary}$ and $BGF_{secondary}$ might not be directly comparable numbers. That is, $BGF_{secondary}$, rather than being a true estimate of a generation rate, reflects a way to relate two very different databases (Needs Survey and NSSS), which have very different data collection methods and sampling approaches, and use them to approximate an increase in biosolids amounts over time. $BGF_{primary}$, on the other hand, relies on engineering estimates and reflects an engineering-based estimate of a generation rate. Furthermore, the volumes of biosolids reported in the NSSS reflect the huge variation in the generation of biosolids by secondary wastewater treatment processes. Primary wastewater treatment processes generate biosolids within in a much narrower range of rates.

used in Table A-2 to calculate the estimate of biosolids generated by POTWs in 1998 using Equation 4 and the projections discussed above. As shown in Table A-2, we estimate that 0.5 million dry tons of biosolids were generated by POTWs using primary treatment processes in 1998 and 6.3 million dry tons of biosolids were generated by POTWs using secondary and above treatment processes in 1998, for a total of 6.8 million dry tons of biosolids.

Table A-1
Estimate of Biosolids Generation Factor

Treatment Category	1988 Biosolids Generation (million U.S. dry tons)	1988 Wastewater Flow (MGD)	Biosolids Generation Factor (U.S. dry tons/MGD)
Primary	0.875	4,300	203
Secondary	5.018	24,400	206

Source: U.S. EPA, 1993a; 1988 Needs Survey (U.S. EPA, 1988).

Table A-2
Estimate of Biosolids Generated by POTWs in 1996 and 1998

Treatment Group	Population Served	% of Total Population Served	1996 Estimate of Flow by POTW Type (MGD)	1998 Estimate of Flow by POTW Type (MGD)	BGF (U.S. dry tons/ MGD)	1996 Estimated Biosolids Generated by POTWs (million U.S. dry tons)	1998 Estimated Biosolids Generated by POTWs (million U.S. dry tons)
Primary	17,177,500	9.05%	2,910	2,700	203	0.6	0.5
Secondary	172,533,400	90.95%	29,300	30,400	206	6.0	6.3
Total	189,710,900	100.00%	32,200	33,100	—	6.6	6.8

Source: 1996 Needs Survey (U.S. EPA, 1996).

A.2.2 Estimate of Biosolids Generation in 1998 from Privately and Federally Owned Treatment Works

Methodology

The NSSS also did not collect data from privately or federally owned treatment works, therefore, an estimate of flow from privately and federally owned treatment works presented in the Part 503 RIA (U.S. EPA, 1993a) was used. This source indicates that flow from these types of treatment works averaged

0.09 MGD in 1991 and that about 5,080 treatment works of this type were known to exist in that year. Thus, 460 MGD of wastewater were estimated to be processed by privately and federally owned treatment works in 1991. We then determined that this flow was 1.5 percent of the flow from POTWs in 1992, according to the 1992 Needs Survey. Also, we assumed that privately and federally owned treatment works operate like POTWs, with the same proportion of wastewater going to primary and secondary treatment processes and with the same BGFs. Therefore, the amount of biosolids estimated for POTWs in 1996 and 1998 was increased by 1.5 percent to account for biosolids generation in 1996 and 1998 by this group of treatment works.

Results

As Table A-3 shows, increasing the 1998 estimates of biosolids generated by POTWs by 1.5 percent produces a 1998 biosolids generation estimate of 6.9 million U.S. dry tons, with about 0.1 million dry tons attributable to privately and federally owned treatment works, or about 0.2 million U.S. dry tons more than that estimated for 1996.

Table A-3
Adjustment for Biosolids Generation From Privately and Federally Owned Treatment Works

Treatment Group	1996 Estimate of Biosolids Generated by POTWs (million U.S. dry tons)	1998 Estimate of Biosolids Generated by POTWs (million U.S. dry tons)	Factor for Privately and Federally Owned Treatment Works	Total 1996 Estimate of Biosolids Generated by All Treatments Works (million U.S. dry tons)	Total 1998 Estimate of Biosolids Generated by All Treatments Works (million U.S. dry tons)
Primary	0.6	0.5	1.5%	0.6	0.6
Secondary	6.0	6.3	1.5%	6.1	6.4
Total	6.6	6.8	1.5%	6.7	6.9[a]

[a]Note: Numbers may not add up properly due to rounding.
Source: Table A-2 and U.S. EPA (1993a).

A.2.3 Total Estimate of Biosolids Generation in 1998

Using these above approaches, we estimate that a total of 6.9 million dry tons were generated in 1998 (see Table A-3). Note that the 1996 estimate is about 6.7 million dry tons, which falls between the two previous estimates of total 1995 and 1996 biosolids production; WEF (1997) estimated 6.4 million dry tons for

1995, while Bastian (1997) estimated 6.9 million dry tons for 1996. Thus, all these recent estimates tend to support each other.[19]

A.3 Estimates of Biosolids Use and Disposal in 1998

Methodology

To estimate the amount of biosolids going to various use or disposal methods, the WEF (1997) survey data were used and applied toward this report's estimate of 1998 biosolids generation total of 6.9 million dry tons (see Section A.2.3). The WEF study was chosen over other data sources to calculate percentages of biosolids going to various use or disposal methods primarily because it provides fairly current 1995 data and also is broken down into various use and disposal categories in such a way as to provide data that are relevant to this report. It also is the most complete source of current data on use and disposal practices because it combines state data with POTW data. This combination of data is useful because some states do not have complete records of biosolids generation, use, and disposal. The data presented in WEF's report also are arranged in categories that correspond most appropriately to the categories of most interest, allowing biosolids management practices to be divided into the use and disposal categories discussed in Sections Two and Three of this report.[20]

WEF divided biosolids management into four categories: land application, surface disposal, incineration, and other. The "other" category included biosolids used for landfill cover, landfill, composting, and other further stabilized or enhanced products. The percentages presented in the WEF report were further adjusted by incorporating the narrative portion of WEF's survey responses to characterize use and disposal methods more precisely for this report. Specifically, since WEF requested and received detailed responses associated with the "other" category on a state basis, it was possible to distribute these responses to the "other" category into the use and disposal categories of interest. Therefore, these responses were distributed into the following categories: surface disposal and landfilling (including landfill, codisposal, and lagoons), incineration

[19]Although the WEF (1997) estimate is for 1995, the difference between the 1996 estimate made in this report and WEF's estimate is about 0.1 million dry tons (using generation trends developed later in this appendix to compare across years).

[20]A drawback to this approach is that WEF's sample of POTWs was composed primarily of larger facilities, as discussed earlier. Smaller POTWs tend to have different use and disposal patterns than larger POTWs. Therefore, using data based on samples of large POTWs could tend to overstate some percentages and understate other percentages of biosolids going to various use and disposal methods. Incineration, for example, is more often practiced by larger POTWs, and smaller POTWs are often located in rural areas where landfill space is still available and land application has been in use for many years. Larger POTWs are often located in urban areas where dwindling landfill space and public perception have prompted some POTWs to institute land application as a method of biosolids management, despite the transport distances involved. Thus, a survey favoring larger POTWs might slightly overstate incineration and might also slightly overstate shifts from landfilling to land application since 1988. WEF, however, has supplemented its POTW data with data from state agencies, lessening the potential for bias.

(including incineration and combustion stabilization processes), advanced treatment (including fertilizer, compost, lawn and garden, potted growing media, lime-stabilized fertilizer, soil amendment, and pelletizing), other beneficial use (including landfill cover and aggregate), and other (all other unidentified processes). This adjustment resulted in a total list of six categories for EPA's needs, including the beneficial use categories of land application, advanced treatment, and other beneficial use as well as the disposal categories of surface disposal and landfilling, incineration, and other (i.e., unidentified processes).

Percentages of biosolids use and disposal for the adjusted categories were applied to the total amount of biosolids generated in 1998, providing an estimate of the dry tons of biosolids going to each use and disposal method (see Table A-4). According to these estimates, 60 percent of biosolids generated in 1998 were beneficially used. Broken down further, 53 percent of biosolids generated in 1998 were land applied or received advanced treatment, such as composting, and were land applied. An additional 7 percent were otherwise beneficially used (3 percent were used as landfill cover and 4 percent were used as aggregate).[21] Table A-4 presents this breakdown of use and disposal methods based on the WEF data. *BioCycle* (1998) also notes a national trend toward beneficial use of biosolids, with 34 states indicating overall that 61 percent of their biosolids are beneficially used.

Table A-4
Biosolids Use and Disposal Based on WEF Survey Data (million U.S. dry tons)

	Beneficial Use				Disposal				
Year	Land Application	Advanced Treatment	Other Beneficial Use	Total	Surface Disposal/ Landfill	Inciner-ation	Other	Total	Total
1998	3.6	0.07	0.5	4.1	1.2	1.5	0.07	2.8	6.9
Percent of Total	52%	1%	7%	60%	17%	22%	1%	40%	100%

Source: WEF (1997) and estimates of the distribution of "other" use or disposal method responses in the WEF survey (see text).

The 52 percent of biosolids going to land application without advanced treatment probably includes some biosolids that did, in fact, receive advanced treatment (defined here as heat treated, lime stabilized, composted, pelletized, or otherwise generally meeting Class A pathogen and vector control

[21] The beneficial use category might be somewhat understated since this report does not distinguish between incineration for disposal and incineration where energy recovery or ash use is practiced, as discussed in Section Two.

requirements—see Section Two), since the WEF survey did not specifically ask respondents to identify amounts of biosolids that received advanced treatment. Thus, we adjusted this figure further, using *BioCycle* (1998) data on composted biosolids, to account more accurately for the amount of biosolids that received advanced treatment before land application.

In *BioCycle* (1998), a total of 34 states provided adequate data for the purposes of this analysis. Data were excluded from some states, such as Louisiana, that reported biosolids volumes in wet tons or that provided breakdowns but no total quantities or total quantities with no breakdowns. Several caveats associated with these data must be noted, however. First, *BioCycle's* data collection effort for biosolids receiving advanced treatment is likely to be the most extensive of all current efforts, since this journal specifically tried to capture data on advanced treatment from the states. Not all states, however, provided sufficient data to clearly break out composted biosolids from biosolids that are normally land applied without advanced treatment because a large portion of advanced treatment biosolids are ultimately land applied.

Second, these data can be used for extrapolation only with the assumption that the "missing" states are not significantly different from the ones that did provide data (an assumption that might not be true). Finally, the data are only as good as the states' records. Some states have accurate recordkeeping, while others, as mentioned in the article, are still in the process of developing accurate recordkeeping. Nevertheless, state data are likely to become more accurate over time.

BioCycle columns "land application," "composting," "lime stabilization," and "heat treatment/pelletizing" were grouped into a beneficial use category and the "landfill," "surface disposal," "incineration," and "other" columns were grouped into a disposal category. A total of 61 percent of the biosolids fall into the beneficial use category and 39 percent fall into the disposal category (compared to the WEF data that indicate that 60 percent could be considered beneficial use and 40 percent disposal, using similar assumptions about classifications). Table A-5 shows how these two sets of data overlap in the area of advanced treatment and other beneficial use.

Table A-5
Comparison of WEF (1997) and *BioCycle* (1998)
Data on Use and Disposal Practices

Data Source	Land Application	Advanced Treatment	Other Beneficial Use	Surface Disposal/ Landfill	Incineration	Other
WEF	52%	1%	7%	17%	22%	1%
BioCycle	47%	14%[a]		19%	20%	1%

Sources: WEF (1997); *BioCycle* (1998).
[a]6.8 percent is composted, 2.7 percent is lime stabilized, and 4.8 percent is heat dried/pelletized.

According to *BioCycle's* data, about 14 percent of the total biosolids appear to receive advanced treatment. As discussed earlier, it is clear from footnotes in the tables, as well as caveats in the text, that the land application category in the *BioCycle* data includes some biosolids that were lime treated or received advanced treatment. Thus, the quantity of biosolids listed in *BioCycle* data treatment categories are underestimated. Even so, these quantities of biosolids that received advanced treatment, according to *BioCycle,* are still larger than the estimates based solely on WEF data. Using this assumption, we estimate that of the 14 percent of the biosolids that *BioCycle* presents as receiving advanced treatment, 7 percent received advanced treatment and were later land applied while an additional 7 percent received advanced treatment and were beneficially used (as landfill cover and aggregate).

Even the *BioCycle*-based estimate might understate the amount of biosolids that receive advanced treatment, therefore, one more approach was used to estimate this figure. According to the NSSS, in 1988 an estimated 1,519,700 U.S. dry tons of biosolids were land applied, of which 329,900 U.S. dry tons were composted, sold, or otherwise likely to have been applied to public contact sites. Biosolids that were composted, sold, or applied to public contact sites (which implies advanced treatment),[22] therefore, constituted 22 percent of all land-applied biosolids in 1988 (U.S. EPA, 1993a). This percentage of biosolids going to land application may actually belong in the advanced treatment category. Thus, we estimate that 12 percent (12 percent is 22 percent of the 53 percent of biosolids that are land applied or receive advanced treatment) of all biosolids generated in 1998 might have been treated and land applied.[23] The percentages presented in Table A-4 were then adjusted to reflect this assumption, as discussed below.

Results

Based on the adjustments to WEF data, out of the total 6.9 million dry tons, 2.8 million dry tons are estimated to have been land applied without any special treatment, such as composting or pelletizing, 0.8 million dry tons are estimated to have been land applied after special treatment, and 0.5 million dry tons are estimated to have been beneficially used in some other manner (i.e., as landfill cover or aggregate), for a total of 4.0 million dry tons estimated to have been beneficially used. It also is estimated that 1.2 million dry tons were surface disposed, 1.5 million dry tons were incinerated, and 0.1 million dry tons were disposed of in another manner.

[22] Given the public access restrictions outlined in the Part 503 Biosolids Rule associated with applying biosolids to public contact sites that have not been further treated (for example, by composting), it is assumed that most biosolids currently applied to public contact sites are likely to have received advanced treatment.

[23] This estimate might still understate the quantity of biosolids treated, since any trend toward advanced treatment of biosolids is not captured using this approach. It is believed, however, that 12 percent receiving advanced treatment and land applied might be a better estimate than 7 percent receiving advanced treatment and then land applied.

Table A-6
Estimates of Biosolids Use and Disposal With Adjustments for Biosolids Receiving Advanced Treatment (million U.S. dry tons)

	Beneficial Use				Disposal				
Year	Land Application	Advanced Treatment	Other Beneficial Use	Total	Surface Disposal/ Landfill	Inciner-ation	Other	Total	Total
1998	2.8	0.8	0.5	4.1	1.2	1.5	0.01	2.8	6.9
Percent of Total	41%	12%	7%	60%	17%	22%	1%	40%	100%

Source: Table A-5 with adjustments for advanced treatment.

The amount of biosolids likely to be going to municipal solid waste facilities can be estimated after some assumptions are made. First, we assumed that all surface-disposed biosolids are disposed of in municipal solid waste landfills.[24] This assumption is reasonable given the small amount of biosolids believed to be disposed of in biosolids monofills, piles, and lagoons or applied to land strictly for disposal (see discussion in Section Two of this report), and given the results of the *BioCycle* (1998) survey, which indicate less than 2 percent of biosolids are surface-disposed among the 34 states with adequate data. Second, for the purpose of this report, it is assumed that no incinerated biosolids are coincinerated with solid waste, although this might occur in rare instances.[25] The advanced treatment category is the only category that is likely to be split between municipal solid waste facilities and others, where municipal solid waste facilities are defined as commercial, noncommercial, or municipal entities that compost municipal solid waste (including yard trimmings) with biosolids. It is estimated that, based on the percentage of biosolids estimated to be used as landfill cover as reported in the WEF (1997) report (3 percent), 0.2 million dry tons of biosolids were used as landfill cover (landfill cover was included in the "other beneficial use" category). At a minimum, 1.4 million dry tons, or 20 percent of total biosolids generated in 1998, are likely to have been managed at municipal solid waste facilities through landfilling or use as a landfill cover. Some additional amount of biosolids might be composted at municipal solid waste facilities (as defined above) for land application, but this quantity is not known. Numbers presented in Section Three include an assumption that half of the advanced treatment category biosolids (0.4 million of the 0.8 million dry tons shown in Table A-6) might be composted at municipal solid waste facilities or at

[24]Based on communication with Bob Bastian, U.S. EPA, May 1997.

[25]Based on communication with Bob Bastian, U.S. EPA, October 1997, and with Steven Levy, U.S. EPA, October 1997.

facilities that manage both biosolids and municipal solid waste, including yard trimmings. Adding the 0.4 million dry tons to the 1.4 million dry tons estimated above to be handled by municipal solid waste or composting facilities brings the total to 1.8 million dry tons or 26 percent of the amount of biosolids estimated to be generated in 1998.

A.4 Projections of Biosolids Generation in 2000, 2005, and 2010

Methodology

This report based projections of biosolids generation for 2000, 2005, and 2010 on trends in wastewater flow rates, which were obtained from available Needs Surveys from the years 1984 to 1996. The amount of flow for each treatment method (primary or secondary treatment) was not available in the Needs Surveys for most years. We, therefore, estimated the flow for each treatment group using the population served for each treatment level as a percentage of the total population served. This calculation is similar to calculations discussed in Section A.2 to determine the Biosolids Generation Factor for each treatment method for a given year's flow.

In each year of the Needs Survey for which data on total flow and population were available (1988, 1992, and 1996), the percentage of those served by primary treatment or secondary treatment to the total population served by all POTWs was calculated.[26] These percentages then were applied to the total flow to estimate the flow attributable to POTWs in each treatment category, as was done earlier for estimating 1996 flow. The trend in flow across the years for which data were available was calculated, and the trend factors were applied to 1996 flows to calculate the flows in 2000, 2005, and 2010 using the estimate of percent change per year and the number of intermediate years.

The BGF for each treatment level was multiplied by flow to estimate the dry tons of biosolids generated, as discussed in Section A.2, for developing the initial estimate of 1996 biosolids generation.

$$\text{Flow Projection (MGD)} \times \text{BGF} = \text{Biosolids Generation (U.S. dry tons)} \quad \textbf{(6)}$$

This calculation was repeated for each of the years 2000, 2005, and 2010 and for each treatment level.

Results

Table A-7 presents the calculations of trends. Given the overall increase in flow due to steady increases in the population served, flow from POTWs using only primary treatment was estimated to be decreasing at an annual rate of about 4 percent, while flow from POTWs using at least secondary treatment methods

[26]Again, secondary treatment for this discussion includes secondary, tertiary, and no discharge categories.

was estimated to be increasing at an annual rate of about 2 percent. With these rates of change, flow was projected for 2000, 2005, and 2010 (see Table A-8).[27]

Based on the above methodology, we estimate that the percentage of total biosolids production attributable to POTWs using primary treatment levels will fall from 8 percent in 1998 (see Table A-3) to 4 percent in 2010. Concurrently, we estimate that total biosolids production will increase by 19 percent from 1998 to 2010. By 2010, a total of 8.2 million dry tons of biosolids are expected to be used or disposed of annually (see Table A-8).

Table A-7
Trend Analysis of Flow (1984 to 1996)

Year	Total Flow (MGD)	Primary as % of Total Population	Secondary as % of Total Population	Primary Flow	Secondary Flow	Trend		
						Primary	Secondary	Total
1984	27,095							—
1986	27,692							+0.02
1988	28,736	15%	85%	4,320	24,416	—	—	+0.04
1990	29,113[a]							+0.01
1992	29,490	12%	88%	3,545	25,945	-0.18	+0.03	+0.01
1994	30,833[a]							+0.05
1996	32,175	9%	91%	2,913	32,175	-0.13	+0.10	+0.04
Trend (1-year)	—	—	—	—	—	-0.04	+0.02	+0.015

Note: Blanks indicate years with missing data.
Source: 1984-1998 Needs Surveys.
[a]Computed as the midpoint between years when data were unavailable.

[27]Over total flow, some variation in the trend was seen over time, with the mid-1980s associated with greater flow increases than the early to late 1990s. After the early 1990s, however, increases picked up again. This is consistent with the accelerating and delaying of wastewater treatment projects that might have occurred. These variations could have been driven by several factors. In the mid-1980s, POTWs were aware that the Construction Grants Program was being eliminated and, thus, might have accelerated some building programs into those years. The Construction Grants Program, which was being phased out in the late 1980s, received its last appropriation in the fiscal year 1990. In the late 1980s and early 1990s, the acceleration of the mid-1980s could have led to a slowdown in wastewater programs, (since many would have been completed), while other POTWs, which had delayed their projects, further delayed them as they investigated new sources of funding. With the onset of the recession in the early 1990s, further delays were likely. Finally, by the mid-1990s, the improving economic conditions and the accumulation of construction programs that could no longer be delayed might have led to the greater increases in flow seen in these years. Taking these factors into account, it is believed that smoothing these trends by averaging them over the years of data available is appropriate.

Table A-8
Wastewater Flow Projections for POTWs and Privately and Federally Owned Treatment Works in 2000, 2005, and 2010

Treatment Group	Wastewater Flow (MGD)			Biosolids Generation Factor	Biosolids Generated (million U.S. dry tons)		
	2000	2005	2010		2000	2005	2010
Primary	2,430	2,000	1,640	203	0.5	0.4	0.3
Secondary	32,280	35,085	38,130	206	6.6	7.2	7.9
Total	34,710	37,085	39,780	—	7.1	7.6	8.2

Source: Tables A-2 and A-7. Includes 1.5 percent additional flow to account for privately and federally owned treatment works under the assumption that these treatment works will follow the same trends as POTWs.

A.5 Use and Disposal of Biosolids in 2000, 2005, and 2010

Methodology

The percentages of biosolids going to the various use and disposal methods were estimated on the basis of expected future trends in factors affecting biosolids use and disposal. As discussed in Section Four, we expect factors favoring the increased recovery of biosolids, including the regulatory environment, technological development, and public acceptance, to contribute to a continuing increase in the beneficial use of biosolids. Concurrently, we anticipate the amount of biosolids going to surface disposal and incineration to decrease, partially due to the rising costs of incineration and, in some locations, landfilling. Amounts incinerated are not expected to decrease rapidly, since this category has grown since 1988.[28] Some small decline in incineration is expected, however, given public concerns about environmental impacts of incineration. (See Section Four for a more detailed discussion of trends.) We then determined the quantities of biosolids going to each use or disposal method on the basis of the projected quantities of biosolids generated in 2000, 2005, and 2010 and the percentage assigned to each method. To account for trends and the projections of biosolids generation for 2000, 2005, and 2010, we first developed percentage estimates for those years (see Table A-9) and then applied these percentages against our previously estimated flow data (Table A-8).

[28]A total of 16.1 percent of biosolids were estimated to have been incinerated in 1988 while 22 percent were estimated to have been incinerated in 1995 (WEF, 1997); note, however, that the WEF (1997) data might somewhat overstate amounts incinerated, as discussed earlier in Section A.3. This conjecture might be supported by *BioCycle* (1998). The data presented in this source indicate that 20 percent of biosolids generated (in the 34 states with sufficient data) were incinerated.

Results

As Table A-10 shows, we expect beneficial use of biosolids to increase from 60 percent in 1998 to 63 percent in 2000, 66 percent in 2050, and 70 percent in 2010. Thus, by 2010, disposal might only account for about 30 percent of all biosolids generated.

Table A-9
Projected Percentages of Biosolids Use and Disposal in 2000, 2005, and 2010

Year	Beneficial Use				Disposal			
	Land Application	Advanced Treatment	Other Beneficial Use	Total	Surface Disposal/ Landfill	Incineration	Other	Total
1998	41%	12%	7%	60%	17%	22%	1%	40%
2000	43%	12.5%	7.5%	63%	14%	22%	1%	37%
2005	45%	13%	8%	66%	13%	20%	1%	34%
2010	48%	13.5%	8.5%	70%	10%	19%	1%	30%

Source: EPA estimates.

Table A-10
Projected Quantities of Biosolids Use and Disposal in 2000, 2005, and 2010 (million U.S. dry tons)

Year	Beneficial Use				Disposal				Total
	Land Application	Treatment/ Land Application	Other Beneficial Use	Total	Surface Disposal/ Landfill	Inciner-ation	Other	Total	
2000	3.1	0.9	0.5	4.5	1.0	1.6	0.1	2.6	7.1
2005	3.4	1.0	0.6	5.0	1.0	1.5	0.1	2.6	7.6
2010	3.9	1.1	0.7	5.7	0.8	1.5	0.1	2.5	8.2

Source: Tables A-9 and A-10.

Based on this assessment of likely trends, we estimate the amount of biosolids to be beneficially used to increase to 4.4, 5.0, and 5.7 million dry tons in 2000, 2005, and 2010, respectively, with 2.6, 2.6, and 2.5 million dry tons, respectively, being disposed of. Compared to current breakdowns between use and disposal methods, a positive trend in the use of biosolids continues in the future, but the trend in disposal becomes slightly negative. The amount of biosolids going to municipal solid waste facilities is projected to be 1.2, 1.2, and 1.0 million dry tons (not including composted biosolids managed by municipal solid waste facilities, as defined earlier, that are not used as landfill cover) in 2000, 2005, and 2010, respectively.[29] Declines in landfilled biosolids are offset slightly by small increases in use of biosolids for landfill cover, but not enough to change the overall decline rate at municipal solid waste facilities. Municipal solid waste facilities, therefore, are likely to be handling at a minimum 17 percent of the 7.1 million dry tons generated in 2000, 16 percent of the 7.6 million dry tons generated in 2005, and 12 percent of the 8.2 million dry tons generated in 2010.

As discussed in Section Four, some portion of the amount estimated to receive advanced treatment might be prepared by municipal solid waste facilities. As much as half (approximately 0.5 million dry tons of the 0.9, 1.0, and 1.1 million dry tons shown in Table A-10) might be handled by these facilities. When these amounts are added to the above estimates, municipal solid waste facilities might manage 1.6 million dry tons of the 7.1 million dry tons generated in 2000 (23 percent), 1.7 million dry tons of the 7.6 million dry tons generated in 2005 (22 percent), and 1.6 million dry tons of the 8.2 million dry tons generated in 2010 (20 percent). These figures include amounts of biosolids disposed of in municipal solid waste landfills, used for landfill cover, or composted for sale or distribution to farmers, contractors, or the general public.

[29]Using the same assumption as above about the relative ratios of landfill cover to aggregate in the other beneficial use category.

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