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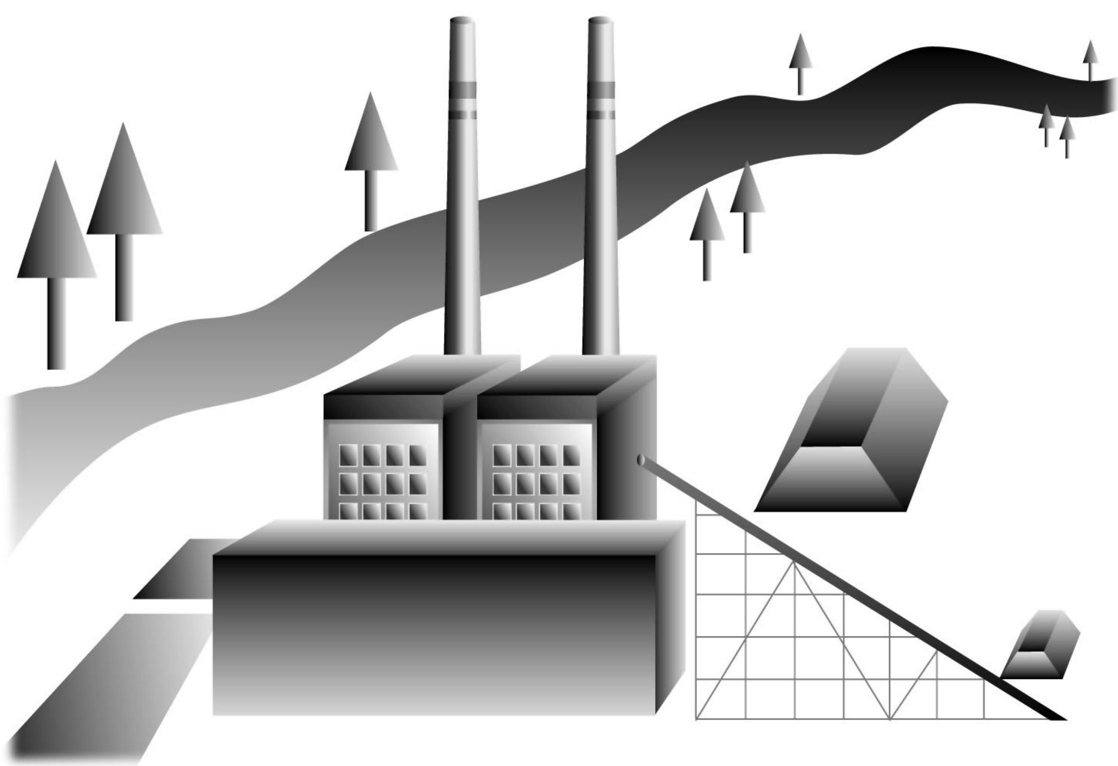
Solid Waste

Report to Congress

Wastes from the Combustion of Fossil Fuels

Volume 2 – Methods, Findings, and Recommendations



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1.0 INTRODUCTION

1.1 BACKGROUND OF REPORT

Section 3001(b)(3)(A)(I) of the Resource Conservation and Recovery Act (RCRA) excludes certain large-volume wastes generated primarily from the combustion of coal or other fossil fuels from being regulated as hazardous waste under Subtitle C of RCRA, pending completion of a Report to Congress required by Section 8002(n) and a determination by the U.S. Environmental Protection Agency (EPA) Administrator either to promulgate regulations under Subtitle C or to deem such regulations as being unwarranted.

In 1988, EPA published the required Report to Congress on wastes from the combustion of coal by electric utility power plants (EPA, 1988). In the Report to Congress, EPA responded to one of the requirements of Section 8002(n) of RCRA. The report, however, did not address the following:

- Wastes generated by utilities burning fossil fuels other than coal
- Wastes from non-utility boilers burning any type of fossil fuel.

In 1991, a suit was filed on behalf of the Bull Run Coalition (an Oregon citizens group) based on the absence of a final ruling by EPA on the wastes studied in the 1988 Report to Congress and on other large-volume wastes generated primarily from the combustion of coal or other fossil fuels. As a result, the Agency entered into a Consent Decree (Civil Action 91-2345, D.D.C. June 30, 1992), which established a schedule for EPA to complete the regulatory determinations for all fossil fuel combustion (FFC) wastes. FFC wastes were divided into two categories: (1) fly ash, bottom ash, boiler slag, and flue gas emission control waste from the combustion of coal by electric utilities and independent commercial power producers, and (2) all remaining wastes subject to RCRA Sections 3001(b) and 8002(n). On August 9, 1993, EPA published a determination for the first category of wastes, concluding that regulation under Subtitle C for these wastes was not warranted. To make an appropriate determination for the second category or "remaining wastes," EPA decided that additional study was necessary. Under the current court-ordered deadlines, the Agency must publish this Report to Congress by March 31, 1999, and issue a regulatory determination by October 1, 1999.

1.2 PURPOSE AND SCOPE OF REPORT

EPA presents this Report to Congress on Wastes from the Combustion of Fossil Fuels as a complement to the 1988 Report to Congress. This report was prepared in response to the requirements of Section 8002(n) of RCRA, which directs EPA to provide a detailed and comprehensive study on the sources and quantities of certain large-volume wastes generated primarily from the combustion of coal or other fossil fuels, potential human health and environmental impacts posed by the management of these wastes, alternatives to current practices, and costs of such alternatives. This report also prepares EPA for its regulatory determination on the remaining wastes, scheduled to be completed by October 1, 1999.

This report addresses the remaining wastes from FFC only. As defined in the 1992 Consent Decree, remaining wastes comprise the following:

- Fly ash, bottom ash, boiler slag, and flue gas emission control wastes from the combustion of coal by electric utility power plants, when such wastes are mixed with, codisposed, cotreated, or otherwise comanaged with other wastes generated in conjunction with the combustion of coal or other fossil fuels

- Any other wastes subject to Section 8002(n) of RCRA, except fly ash, bottom ash, boiler slag, and flue gas emission wastes from coal combustion by electric utilities.

For the purposes of this report, EPA has termed the first category of remaining wastes listed above as "comanaged utility coal combustion wastes" ("comanaged wastes" for short). EPA further subdivided the second category of remaining wastes as follows:

- Wastes from the combustion of mixtures of coal and other fuels ("coburning") by utilities
- Wastes from the combustion of coal by non-utilities
- Wastes from fluidized bed combustion of fossil fuels (by utilities and non-utilities)
- Wastes from the combustion of oil (by utilities and non-utilities)
- Wastes from the combustion of natural gas (by utilities and non-utilities).

In this study, EPA presents its current understanding of the generation, management, disposal, and reuse of these remaining wastes from FFC. EPA addresses the following eight study factors required by Section 8002(n) of RCRA:

1. The source and volumes of such materials generated per year

2. Present disposal and utilization practices

3. Potential danger, if any, to human health and the environment from the disposal and reuse of such material

4. Documented cases in which danger to human health or the environment from surface runoff or leachate has been proved

5. Alternatives to current disposal methods

6. The costs of such alternatives

7. The impacts of those alternatives on the use of coal and other natural resources

8. The current and potential utilization of such materials.

1.3 CONTENTS AND ORGANIZATION OF REPORT

The report is organized into seven chapters that address the study factors required under Section 8002(n) of RCRA. Chapter 2 provides an overview of FFC in the United States, including a brief description of the utility and non-utility sectors and a discussion of projected trends for the industry. Chapters 3 through 7 parallel the categories of remaining wastes listed above in Section 1.2. Chapter 3 focuses on comanaged utility coal combustion waste and also covers coburning by utilities. Chapter 4 examines non-utility coal combustion waste. Chapters 5 and 6 discuss fluidized bed combustion wastes and oil combustion wastes, respectively. Chapter 7 focuses on natural gas combustion wastes. Chapters 3 through 6 each provide overviews of their relevant sectors; describe the wastes generated, their characteristics, and volumes; and examine current waste management practices, potential and documented dangers to human health and the environment, existing regulatory controls, waste management alternatives, and costs and economic impacts. Chapter 7 presents a brief overview of natural gas combustion technology (additional discussion of natural gas combustion wastes is not warranted because of minimal waste generation). Finally, each of the chapters presents the Agency's findings and tentative recommendations for the regulatory determination.

1.4 GENERAL METHODS AND INFORMATION SOURCES

1.4.1 Industry Overview, Waste Generation, and Current Management Practices

The introductory, waste generation, and current management practices sections of this report provide a general overview and background on the FFC industry. Much of the descriptive information in these sections was adapted from the standard industry texts and other references listed at the end of this report. Statistical data describing the industry, combustion technologies, waste generation rates, and waste management practices were derived from several major sources, including the following:

1. The 1994 Edison Electric Institute (EEI) Power Statistics Database (EEI, 1994), which incorporates the 1993 Energy Information Administration (EIA) 767 Database

2. The 1990 U.S. EPA National Interim Emission Inventory (EPA, 1990)

3. The 1997 Council of Industrial Boiler Owners (CIBO) Non-Utility Survey (CIBO, 1997a)

4. The 1997 CIBO Fluidized Bed Combustion (FBC) Survey (CIBO, 1997b)

5. The 1997 Electric Power Research Institute (EPRI) Comanagement Survey (EPRI, 1997a)

6. EPRI's report summarizing results of the Comanagement Survey (EPRI, 1997b)

7. EPRI's report, *Oil Combustion By-Products: Chemical Characteristics, Management Practices, and Groundwater Effects* (EPRI 1998a)

8. CIBO's report, *Report to the U.S. Environmental Protection Agency on Fossil Fuel Combustion Byproducts from Fluidized Bed Boilers* (CIBO, 1997c)

9. The U.S. Department of Energy's (DOE) *Coal Combustion Waste Management Study* (DOE, 1993).

Publications 6 through 9 are available in the EPA docket. Although the electronic databases (1 through 5) are not in the docket, EPA's methodology for analyzing these databases and the results of these analyses are presented in EPA documents prepared in support of this study (i.e., the *Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Industry Statistics* and other documents). These documents can be found in the EPA docket.

The waste management sections of this report also describe current beneficial uses of FFC wastes. To characterize the prevalence, methods, and effects of beneficial use of FFC wastes, EPA compiled and reviewed a variety of publicly available information. The purpose of this review was to identify (1) those uses with the potential to expand as alternatives to current management practices, and (2) those uses with the potential for environmental impacts worthy of further consideration in the risk assessment portion of this study. Literature reviewed by EPA included descriptions of existing and emerging uses, feasibility studies, environmental performance studies, economic evaluations, reviews of regulatory requirements, case studies, and usage statistics. The specific sources reviewed are identified in the Technical Background Document titled *Beneficial Use of Fossil Fuel Combustion Wastes*, available in the EPA docket.

1.4.2 Waste Characterization

To describe the physical, chemical, and leachate characteristics of FFC wastes, EPA relied upon analytical data submitted voluntarily by the industry. In summarizing and performing statistical analyses of these data, EPA used several standard procedures. First, values reported as below a detection limit were assigned a value equal to one-half the detection limit for purposes of statistical analysis. Second, because the Agency was more interested in variation *between* facilities than variation *within* individual facilities, much of the characterization was performed using facility-averaged values. That is, multiple measurements from a single site were averaged, and the resulting population of facility averages was used to generate summary statistics.

Major sources used to characterize FFC wastes include the following:

1. EPRI site reports for coal-fired utilities comanaging wastes (EPRI, 1991, 1992, 1994a, 1994b, 1996a, 1996b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, 1997l)
2. EPRI's *Guidance for Comanagement of Mill Rejects at Coal-fired Power Plants* (EPRI, 1999)
3. EPRI's *PCDDs and PCDFs in Coal Combustion By-Products* (EPRI, 1998b)
4. EPRI's *Characterization of Byproducts from Coburning with Coal in Utility Boilers* (EPRI, 1997m)
5. EPRI's oil combustion byproducts database (EPRI, 1997n)
6. Characterization data submitted in response to CIBO's FBC Survey (CIBO, 1997b)
7. Summary data for coal-fired stoker boilers provided by CIBO (CIBO, 1998).

Publications 1 through 4 are available in the EPA docket. Although the electronic databases (5 through 7) are not in the docket, EPA's methodology for analyzing these databases and the results of these analyses are presented in EPA documents prepared in support of this study (i.e., the *Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Waste Characterization* and other documents). These documents can be found in the EPA docket.

1.4.3 Overview of Risk Assessment Methodology and Results

EPA conducted a very comprehensive multi-pathway risk assessment for this report. For both human health and ecological risk, a wide range of exposure paths, exposure routes, and receptors was considered. Figures 1-1 and 1-2 depict the full range of such combinations. This comprehensive approach reflects advances in risk assessment techniques made since the previous fossil fuel combustion Report to Congress (1988) and the previous Regulatory Determination (1993).

Figure 1-1. Exposure Pathways for Human Receptors

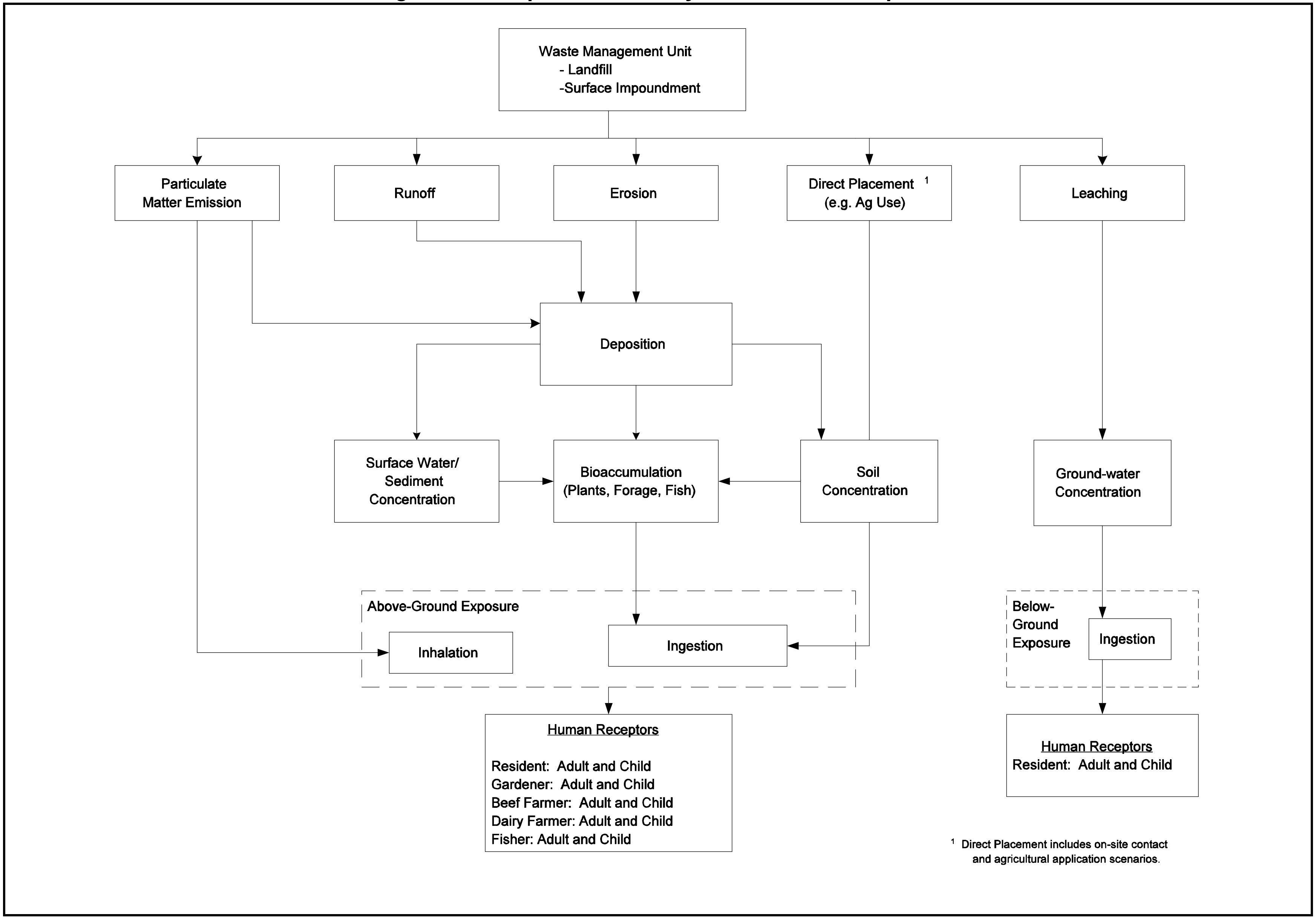
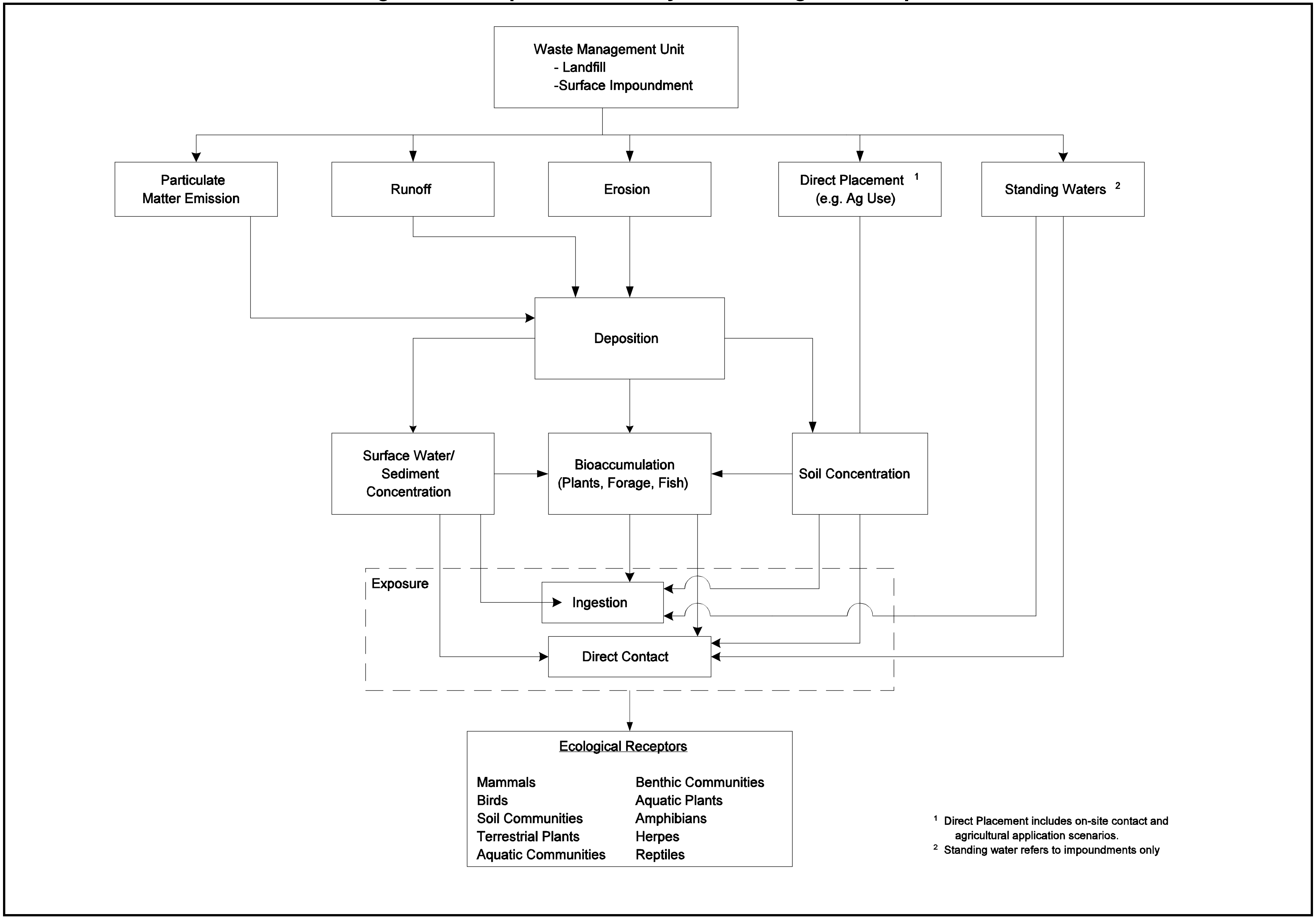


Figure 1-2. Exposure Pathways for Ecological Receptors



The methodology involved, first, preliminary "screening" to determine if "worst-case" contaminant levels (measured levels close to or within the source) present a threat to human health, and second, if a potential threat was determined in the "screening" phase, fate and transport modeling to determine exposure to a receptor. For ecological risk assessment, the emphasis was on modeling to determine exposure and risk to any of the multitude of possible receptors (see Figure 1-2).

As part of the risk assessment process for this study, EPA submitted the multi-pathway risk assessment to external peer review. The human health ground-water risk assessment and non-ground-water risk assessment were reviewed by two primary peer reviewers, and the ecological risk assessment was reviewed by two different primary peer reviewers. Subsequent to peer review, EPA performed a variety of sensitivity and uncertainty analyses to derive a best estimate of risks for each of the scenarios modeled. Peer review comments and sensitivity and uncertainty analyses can be found in the docket.

The "screening" phase of the analysis was purposely structured to avoid the likelihood of removing from further analysis any contaminant that *might* pose a threat. While the 1993 screening analysis prescribed for ground water that measured contaminant levels exceed selected health-based numbers by a factor of 10, and that at least 10 percent of samples must show such an exceedance, this risk assessment prescribed no such threshold. *Even one health-based number exceedance* for a reported maximum concentration level required modeling. This was a very conservative approach; in essence, modeling dictated that very few chemicals were screened out. The same approach guided the non-ground-water human health assessment (no non-ground-water modeling was accomplished in 1993).

The primary ground-water model utilized by EPA's Office of Solid Waste (OSW), known as EPACMTP (see Section 3.4), provided the basis for the risk results denoted. This model has been peer reviewed as well as reviewed by EPA's Science Advisory Board. In an effort to confirm general trends and results, and to provide further insight into the sensitivity of results to changes in significant input variables, the electric power industry's MYGRT model was run in selected cases. While there were differences in modeled results, general confirmation of times to peak concentration were found. The methodology used for the non-ground-water analysis, for both human health and ecological risk, involves a complex series of linked spreadsheets embodying a multitude of input variables; as noted, all modeling procedures are described in detail in Sections 3.4, 4.4, 5.4, and 6.4, and in the documents found in the docket in support of this Report to Congress.

Under RCRA, EPA's OSW is required to conduct nationwide risk assessments. Where disposal facilities are located regionally, the analysis is of course tailored to regional conditions. For this report, the four industry segments—coal-fired utilities, oil-fired utilities, combustors utilizing fluidized bed technology (FBCs), and the amorphous collection of "all other" burners of any fossil fuel—presented different modeling problems. For the essentially nationwide sets of coal-fired utilities and the "all other" collection, EPA used a nationwide environmental data set; for both the FBC facilities and the oil-fired utilities, the data sets were tailored as much as possible to the regions where these units are found.

All data for the risk assessments but for basic nationwide or regional descriptive environmental data (which were taken from existing EPA data bases) were provided voluntarily by the industry potentially to be regulated. As noted in the documents provided for the docket, the industry-provided data varied in their representativeness. For the oil-fired utilities and the FBC facilities, some 30 percent of the sites were well represented. For the coal-fired utilities, fewer than 1 percent of landfills were represented in industry-collected samples, and some 3 percent of impoundments were so represented. However, previously existing leachate data were used to supplement the industry samples.

In essence, a great deal of judgment had to be exercised to provide any assurance that the contaminant data provided by industry were sufficient for analysis. A very extensive sensitivity analysis was performed to aid in this process (for details, see in particular the documents provided in the docket supporting this Report to Congress). All modeling input variables of known modeling significance were varied alone and in combinations of up to three at a time to test for uncertainty. Still, industry-provided contaminant data presented a problem. EPA tested these at up to three times reported levels but did not test for the possibility that even higher levels might exist. Uncertainty still exists as to the nationwide representativeness of this key input variable.

For minefills, wherein ash wastes are disposed, EPA is continuing its analysis. This includes both surface and deep mines. While surface minefills may be simulated much like landfills, deep minefills present many complex problems. Also, the industry, depending on the particular siting issues, has many mitigating options available. A discussion of this issue is found in Section 3.4 of this Report to Congress.

1.4.4 Damage Analysis

In its evaluation of remaining FFC wastes, EPA evaluated damage cases in the same way as in previous Reports to Congress for RCRA §8002 wastes (i.e., the 1993 Report to Congress on Cement Kiln Dust and the 1990 Report to Congress on Special Wastes from Mineral Processing). Specifically, EPA used a “test of proof” in these reports to identify documented damage cases. As discussed in later sections of this Report to Congress, EPA identified a number of cases in which contaminants are present in environmental media surrounding FFC sites, but the available data were insufficient to qualify the sites as documented damage cases based on the “test of proof” described below.

Section 8002(o)(4) of RCRA requires that EPA’s study of remaining FFC wastes examine “documented cases in which danger to human health or the environment has been proved.” To address this requirement, EPA defined danger to human health or the environment in the following manner. First, danger to human health includes both acute and chronic effects (e.g., directly observed health effects such as elevated blood-lead levels). Second, danger to the environment includes the following types of impacts: (1) significant impairment of natural resources (e.g., contamination of any current or potential source of drinking water with contaminant concentrations exceeding drinking water and/or aquatic ecological standards), (2) ecological effects resulting in degradation of the structure or function of natural ecosystems and habitats, and (3) effects on wildlife resulting in damage to terrestrial or aquatic fauna (e.g., reduction in species’ diversity or density, or interference with reproduction).

As stipulated in RCRA §8002(o)(4), EPA is statutorily required to examine proven cases of danger to human health or the environment. Accordingly, EPA developed “tests of proof” for the above-mentioned Reports to Congress to determine if documentation available on a case provides evidence that danger or damage has occurred, and uses the same methodology here. These “tests of proof” comprise three separate tests; a case that satisfies one or more of these tests is considered “proven.” The tests are as follows:

- **Scientific investigation.** Damages are found to exist as part of the findings of a scientific study. Such studies should include both formal investigations supporting litigation or a state enforcement action, and the results of technical tests (such as monitoring of wells). Scientific studies must demonstrate that damages are significant in terms of impacts on human health or the environment. For example, information on contamination of a drinking water aquifer must indicate that contaminant levels exceed drinking water standards.

- **Administrative ruling.** Damages are found to exist through a formal administrative ruling, such as the conclusions of a site report by a field inspector, or through existence of an enforcement action that cited specific health or environmental damages.

- **Court decision.** Damages are found to exist through the ruling of a court or through an out-of-court settlement.

For many sites studied for this report, EPA employed a fourth "test." Specifically, damages must be attributable to FFC wastes. The non-utility universe encompasses many types of facilities. EPA found that FFC wastes could be found at many industrial sites at which damages have occurred. However, the observed damages were generally unrelated to FFC wastes. Therefore, to be considered a proven damage case, EPA required sufficient information to determine that FFC wastes were not only present, but clearly implicated, in the reported damage.

1.4.5 Existing Regulatory Controls Analysis

This report characterizes regulations addressing air pollution, water pollution, and solid and hazardous waste. Air regulations were analyzed primarily for their historical and potential future impact on waste generation. The analysis focused on federal programs and was based on a review of the relevant regulations and experience with the application of these programs to the FFC universe.

Water regulations were analyzed to provide background on their impact on waste management practices and because of their potential for controlling direct release of FFC wastes to surface water. Because state programs implement and must be at least as stringent as the federal program, the analysis focused on federal requirements as a lowest common denominator. As for air regulations, the analysis was based on a review of the relevant regulations and experience with the application of these programs to the FFC universe.

The analysis of solid and hazardous waste regulations focused on state implementation of solid waste controls on FFC wastes under Subtitle D of RCRA. State solid waste management regulations were analyzed first on a nationwide scale, using survey data for all 50 states, and second on a more detailed level, using case studies of selected states.

For analysis on a nationwide scale, data on state solid waste management regulations in all 50 states were compiled from four sources, all of which are available in the EPA docket:

1. The Association of State and Territorial Solid Waste Management Officials' (ASTSWMO) *Non-municipal, Subtitle D Waste Survey* (ASTSWMO, 1996)

2. EPA's *State Requirements for Industrial Non-Hazardous Waste Management Facilities* (EPA, 1995b)

3. A survey of state waste management controls conducted as part of CIBO's *Report to the U.S. Environmental Protection Agency on Fossil Fuel Combustion Byproducts from Fluidized Bed Boilers* (CIBO, 1997c)

4. The American Coal Ash Association's (ACAA) *State-by-State Summaries of Solid Waste Regulations* (ACAA, 1996).

The ACAA summaries were used to characterize the exemption status of FFC wastes in all 50 states. The ASTSWMO and CIBO survey results were combined to characterize the types of regulatory controls imposed on FFC waste management units. The EPA review data were used to describe daily cover/fugitive dust controls (not surveyed by ASTSWMO) to confirm the other survey data for the states with the largest capacity in each generating sector, and to provide additional descriptive information.

The ASTSWMO and CIBO results agreed in the majority of cases. In cases in which the two sources disagreed, the ASTSWMO data were used because the results were more detailed and better documented. In the analysis, the combined data were used to generate summary statistics on the nature and stringency of state solid waste management controls in all 50 states. In the case of coal combustion wastes, these data also were compared to historical data from the 1988 Report to Congress (EPA, 1988) to draw conclusions about trends in state regulation.

To further characterize state implementation, EPA examined in detail programs in several (two to five) selected states for each FFC waste sector. The specific states were selected to maximize the percentage of generating capacity covered in each sector while making efficient use of available resources. For example, much of the regulatory controls information was collected during visits to state agencies to collect waste management and damage case information. The analysis of each state included review of regulations, discussions with state officials, comparison with observed management practices, and review of published summary information, including that which can be found in the CIBO report and the survey publications cited above. The results of this detailed analysis are summarized here and presented in more detail in the supporting documents contained in the EPA docket.

1.4.6 Waste Management Alternatives

Because the risk assessment identified potential risks from unlined waste management units and in certain other situations as noted below, EPA considered alternative risk mitigation strategies. The alternative management practices considered depended on the waste and the current practice for which potential risk was found. The appropriate chapters of this report discuss these alternatives in detail. They may be summarized as follows:

- The ground-water risk assessment identified potential risk for comanaged waste from coal-fired utilities managed in landfills and surface impoundments, non-utility coal combustion waste managed in landfills, fluidized bed combustion waste managed in landfills, and oil combustion waste managed in landfills and solids settling basins. The risk mitigation alternatives for these cases are consistent with the design requirements for municipal solid waste landfills under Subtitle D of RCRA. The alternatives are, in fact, similar to current management practices at some FFC facilities (e.g., facilities with lined waste management units). Thus, the alternatives considered would reflect a change in management practices only for part of the FFC universe (e.g., that part using unlined disposal).

- The above-ground risk assessment identified potential risk for comanaged waste from coal-fired utilities, non-utility coal combustion waste, and fluidized bed combustion waste when used in agricultural applications. For these cases, a variety of management alternatives was considered, ranging from a ban to a concentration-based limit on wastes intended for agricultural use.

- The ecological risk assessment identified potential risk from immersion in surface impoundments containing comanaged waste from coal-fired utilities. This report does not suggest specific mitigation alternatives for this ecological risk.

- EPA identified comanagement of mill rejects (specifically, their pyrite component) with coal combustion wastes as a practice of potential concern. Because the Agency currently is evaluating a voluntary industry proposal for mill reject management, this report does not consider specific mitigation alternatives for mill rejects.

- EPA identified minefilling of FFC wastes as a practice of potential concern. The Agency currently is seeking more information on this practice.

1.4.7 Cost and Economic Impact Analysis

For FFC wastes disposed in landfills and impoundments/basins, EPA analyzed the costs for economic impacts of the alternative Subtitle D management practices as follows:

- The Agency estimated the incremental compliance costs associated with Subtitle D compliance. The calculation of incremental cost made allowances for those sites already in compliance. (EPA is aware that some combustors have undertaken a liner program in conjunction with state programs.)

- Based on the incremental compliance costs, EPA analyzed economic impacts at the firm level.

- Finally, based on the incremental compliance costs, EPA assessed economic impacts at the industry level.

This analysis was very detailed, as discussed in Sections 3.7, 4.7, 5.7, and 6.7.

For pyrite management and for agricultural use alternatives, the Agency has not as yet conducted a cost and impact analysis. The pyrite management proposals are the industry's, voluntarily submitted for Agency review, while the costs associated with agricultural use alternatives are expected to be very low in view of the very limited and competitive market for such materials. (The small amounts of ash going to agricultural use can be accommodated easily by other disposal practices. Also, it should be kept in mind that the utility industry alone generates more than $200 billion in annual sales; the agricultural use market, to the extent that it exists at all as a viable market, pales in comparison.)

At the time of publication of this Report to Congress, both risk assessment and potential risk mitigation issues relating to minefill disposal remain unresolved. With respect to surface mines, EPA is considering, subject to stakeholder comment, requiring risk mitigating actions as discussed in Section 3.4 of this report. In many cases, these are already practiced. With respect to underground mines, EPA is also considering requiring certain risk mitigating actions, as denoted in Section 3.4. Cost and economic impact analysis will be conducted as these issues are clarified.

No cost or economic analysis was conducted for mitigating the potential ecological risk. This is not to suggest that EPA believes the analysis to be without merit; such risks have also been reported in prior studies. Stakeholder comment is invited on this issue.

1.5 DECISION-MAKING PROCESS

In the Agency's part 1 fossil fuel combustion regulatory determination (58 FR 42466, 8/9/93), the Agency applied a three-step decision-making process. Under this procedure, the Agency first considers the potential impacts of the wastes in question on human health and the environment. If EPA finds there may be significant impact, the Agency next considers whether there is a need for regulation under RCRA Subtitle C in light of existing waste management practices and existing regulatory controls imposed by states under authorities other than Subtitle C. The Agency also considers whether Subtitle C would effectively address problems associated with the waste without imposing significant unnecessary controls. Finally, if the Agency concludes that additional regulation under Subtitle C is warranted, EPA considers the potential economic impacts and affects on operations and beneficial uses of the wastes from such regulation on the industry.

In this report, EPA has continued to consider the factors previously utilized in the three-step decision-making process, since the Agency believes that these factors appropriately reflect the statutory criteria in Section 8002 of RCRA that EPA must consider in issuing this report. The Agency has modified somewhat, however, how those factors are considered in formulating its recommendations. Rather than apply the statutory criteria in rigid, stepwise fashion, EPA has considered the totality of the relevant factors (i.e., the potential environmental and human health impacts, the need, if any, for additional regulation and, finally, the potential impacts of imposing regulation under subtitle C in developing the report's recommendations). The step-wise approach to making regulatory determinations assumes that it is possible to reach readily discernable, yes-or-no decisions regarding each step in the decision-making process. As we gain experience in evaluating Bevill wastes, however, we have learned that such clear-cut answers may not be possible for each individual decision-making criterion, and that it may be necessary to balance all the relevant factors to reach the appropriate recommendation. For example, where a particular waste poses some potential risk, but existing controls are wholly inadequate and regulation under subtitle C would not cause severe economic dislocation, a determination to regulate the waste may be appropriate. Conversely, where a waste poses more substantial risks but existing controls are generally adequate and the costs of subtitle C controls would be substantial, continuing the exemption might be the appropriate outcome. In both cases, each individual decision criterion may not yield a definitive regulatory determination. Instead, considering the totality of the relevant factors would be most likely to yield a rational conclusion consistent with our statutory mandate. Thus, EPA will take this approach in this report and the regulatory determination to follow, which the Agency believes is consistent with the broad decision-making discretion that Congress intended EPA to exercise in making regulatory determinations for Bevill wastes.

2.0 OVERVIEW OF INDUSTRIES USING FOSSIL FUEL COMBUSTION

This chapter provides an overview of the fossil fuel combustion (FFC) in the United States, compares in general terms the industry sectors covered by this report, and discusses future trends for the industry. This chapter also addresses discusses generic issues, such as environmental justice, that are not specific to the waste type categories that are the subject of the remaining chapters of this report.

2.1 DESCRIPTION AND COMPARISON OF INDUSTRY SECTORS

In 1997, the United States produced more than 72 quadrillion British thermal units (Btu) of energy. More than 80 percent of this total was produced from fossil fuels, primarily coal, natural gas, and oil. The United States also consumed more than 25 quadrillion Btu of imported energy, nearly all of it in the form of oil or natural gas. After accounting for exports, total U.S. energy consumption in 1997 was 94.2 quadrillion Btu, with the majority of consumption in fossil fuels (EIA, 1997e). A substantial portion of these fossil fuels were combusted by entities in two major categories: utilities and non-utilities.

Utilities combust fossil fuels to produce electricity, which is then sold to end users. For purposes of this report, the utility sector comprises both traditional electric utilities and independent power producers that are not engaged in any other industrial activity. Utilities include private investor-owned operations and public nonprofit organizations. Using a variety of fuels and technologies, the utility sector accounts for the majority of electricity generated in the United States. This electricity is produced not only by FFC, but also by nuclear power plants, hydroelectric facilities, and alternative sources (e.g., solar and geothermal). FFC, however, is the most significant of these sources, accounting for nearly 67 percent of the electricity produced in 1997. Coal is the most significant of the fossil fuels, accounting for more than 50 percent of electricity produced (EIA, 1998a).

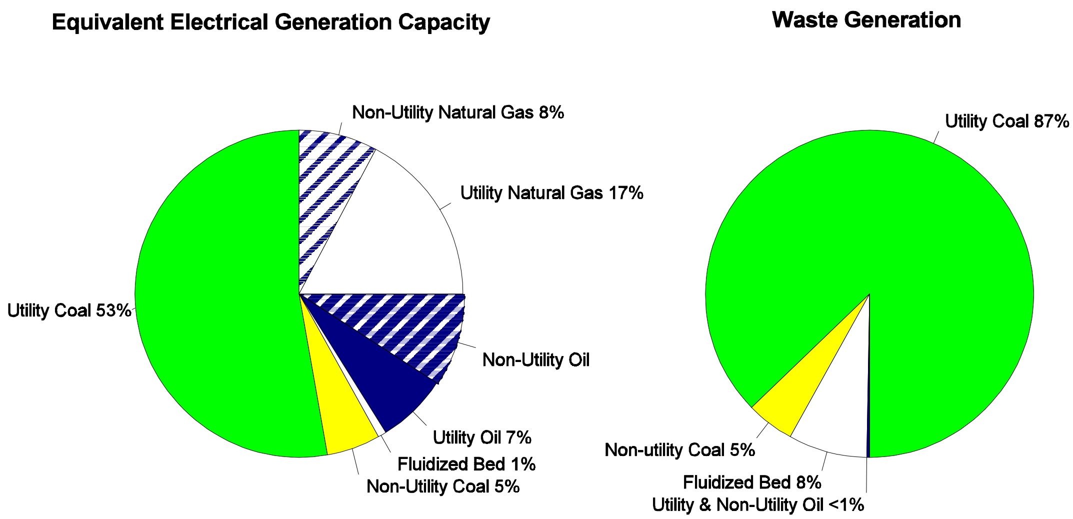
Electricity production is not the primary industrial activity of non-utility FFCs. The non-utility sector encompasses a wide variety of industrial, commercial, and institutional facilities with varying environmental and economic characteristics. Industrial facilities combust fossil fuels to generate power, heat, or steam for use in manufacturing processes. Many of these industrial non-utilities are found in the chemical manufacturing, pulp and paper, food products, and metals industries (EPA, 1990). Commercial facilities include retail, assembly, warehouse, and office establishments that combust fossil fuels for uses including heating, cooling, ventilating, lighting, cooking, refrigeration, and powering office equipment. Institutional facilities include educational, health care, government, and other public buildings that combust fossil fuels for uses similar to those at commercial facilities. Combustion of fossil fuels accounts for more than 70 percent of the energy delivered to non-utilities. Electricity purchased from utilities accounts for most of the rest (EIA, 1998a).

For purposes of this report, the utility and non-utility FFC industry is divided into the following sectors:

- Coal-fired utilities (including utilities that coburn coal and other fuels)
- Coal-fired non-utilities
- Fluidized bed combustion facilities, both utility and non-utility
- Oil-fired facilities, both utility and non-utility
- Natural gas-fired facilities, both utility and non-utility.

Figure 2-1 compares the relative size of each of these sectors, both in terms of equivalent electricity generating capacity and FFC waste generation. Coal-fired utilities dominate the industry in terms of electrical generating capacity *and* quantity of waste generated. For purposes of this study, large-volume wastes from coal-fired utilities are relevant only when they are comanaged with low-volume combustion wastes. As discussed in Chapter 3, however, the majority of utility coal combustion wastes are comanaged. Therefore, the share of waste generation shown in Figure 2-1 for coal-fired utilities generally represents comanaged coal combustion waste.

Figure 2-1. Relative Size of Fossil Fuel Combustion Industry Sectors*



* Percentages shown are estimates only.
Sources: EEI, 1994; EPA, 1990; CIBO, 1997c (for waste generation, see Chapters 3–7)

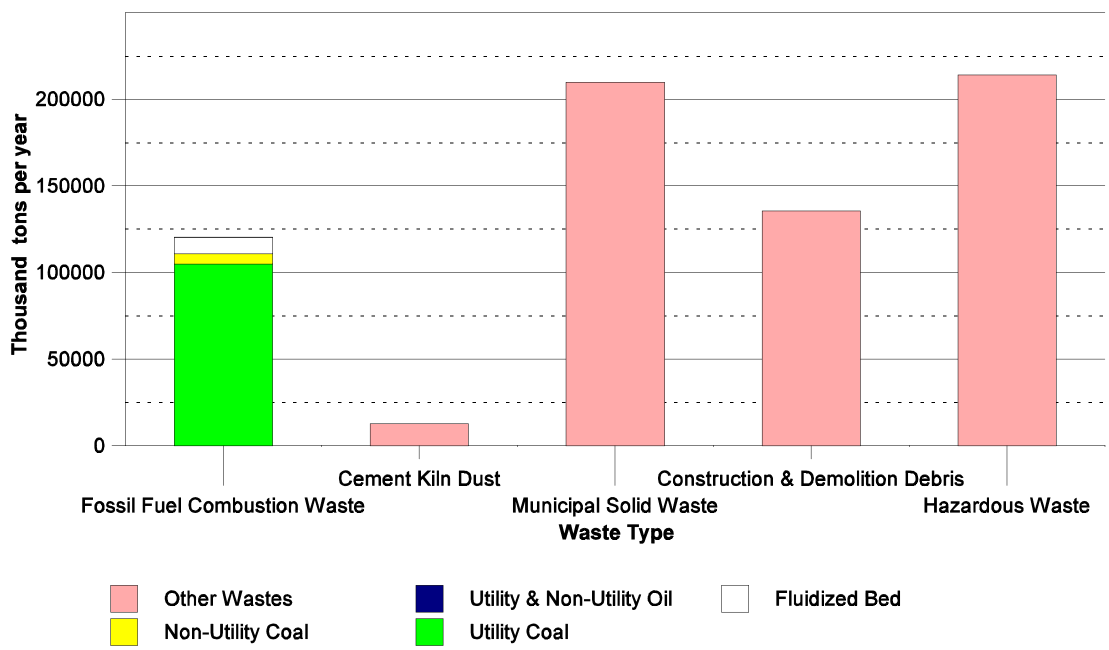
While coal accounts for a relatively smaller share of non-utility electricity generating capacity, coal-fired non-utilities still generate a significant quantity of waste. Fluidized bed combustion facilities account for only a fraction of electrical generating capacity, but generate a relatively large quantity of waste. Oil-fired facilities, in spite of their share of generating capacity, generate relatively small amounts of waste. Natural gas combustion generates virtually no solid waste.

For additional perspective, Figure 2-2 compares FFC waste generation to the generation of other types of waste in the United States. This figure shows the relatively large quantity of waste generated by FFC and emphasizes the significance of coal combustion as a contributor to the quantities generated.

2.2 TRENDS

The U.S. Department of Energy's Energy Information Administration (EIA) projects that total U.S. energy consumption will increase from 94 to 119.9 quadrillion Btu between 1997 and 2020, an average annual increase of 1.1 percent. This growth in consumption is expected to include increasing demand for electricity from utilities as well as increasing consumption of fossil fuels at non-utilities (EIA, 1998a).

Figure 2-2. FFC Waste Generation Compared to Other Wastes



Sources: EPA, 1993a; EPA, 1998a; EPA, 19987b; EPA, 1997a

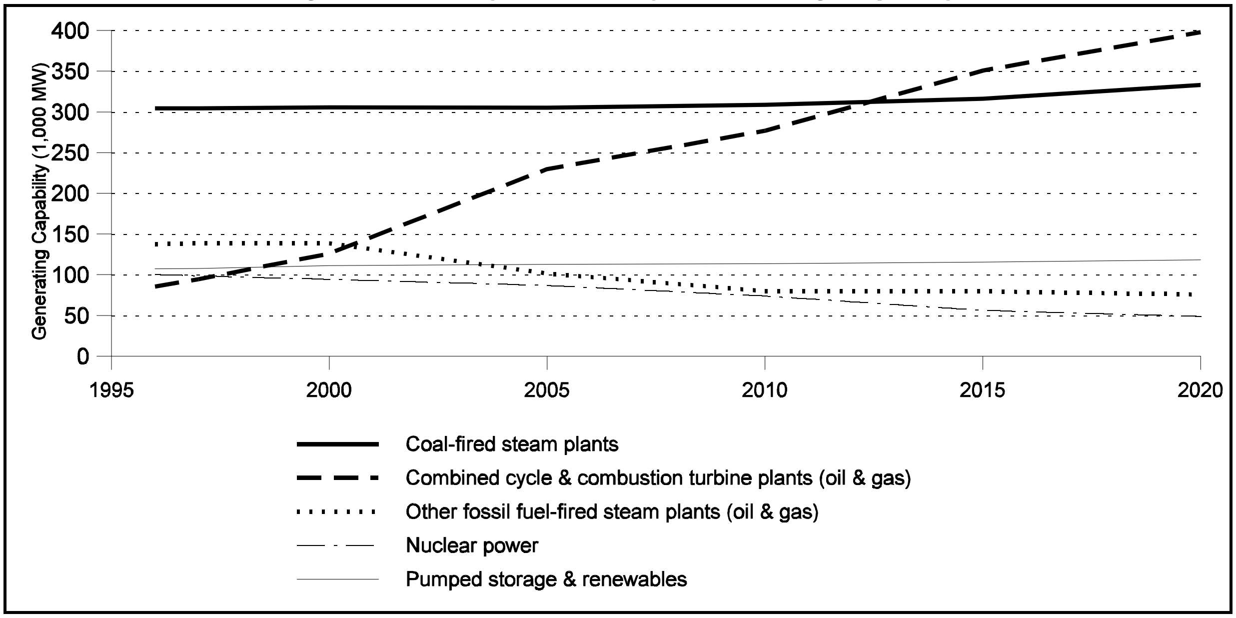
While this represents a decrease in the rate of growth of demand for electricity, new utility generation capacity still will be needed to meet the additional demand and to replace retiring units (including units representing half of current nuclear capacity). The EIA projects that 363 gigawatts of new generation capacity, representing more than 1,000 new plants, will be needed by 2020 (EIA, 1998a).

This new capacity will drive a gradual change in the fuels used by the utility sector. Changes in power plant technology and economics, along with recent changes in environmental regulations, will limit the construction of new coal-fired utility plants (EIA, 1998a). In estimating the impact of recently proposed new air emissions regulations, EPA predicted that coal-fired capacity would not increase through 2010 (EPA, 1997b). The EIA similarly predicts only limited additions to coal-fired capacity through 2010. Instead, utilities will invest in combined-cycle or combustion turbine technology fueled by natural gas or both oil and gas. Between 2010 and 2020, however, the EIA projects increasing demand for new coal-fired plants due to increasing natural gas costs and nuclear retirements. As a result of increasing oil prices, oil-fired steam plants are expected to be replaced by turbine technologies through 2020 (EIA, 1998a). Figure 2-3 shows the EIA's projections for utility capacity reflecting these changes.

Although limited new coal-fired capacity is expected through 2020, coal consumption by utilities is expected to increase due to increased utilization of existing generating capacity. This increase in coal consumption is not expected to match the rate of increase in previous decades, however. Natural gas consumption is expected to increase dramatically, consistent with the addition of new gas-fired capacity. Oil consumption by utilities is expected to fall significantly as a result of expected increases in oil prices (EIA, 1998a).

For non-utilities, the EIA projects modest growth in energy use. In the industrial sector, increasing energy demand associated with increasing industrial output will be moderated by more energy

Figure 2-3. Projected Utility Generating Capacity



Source: EIA, 1998a

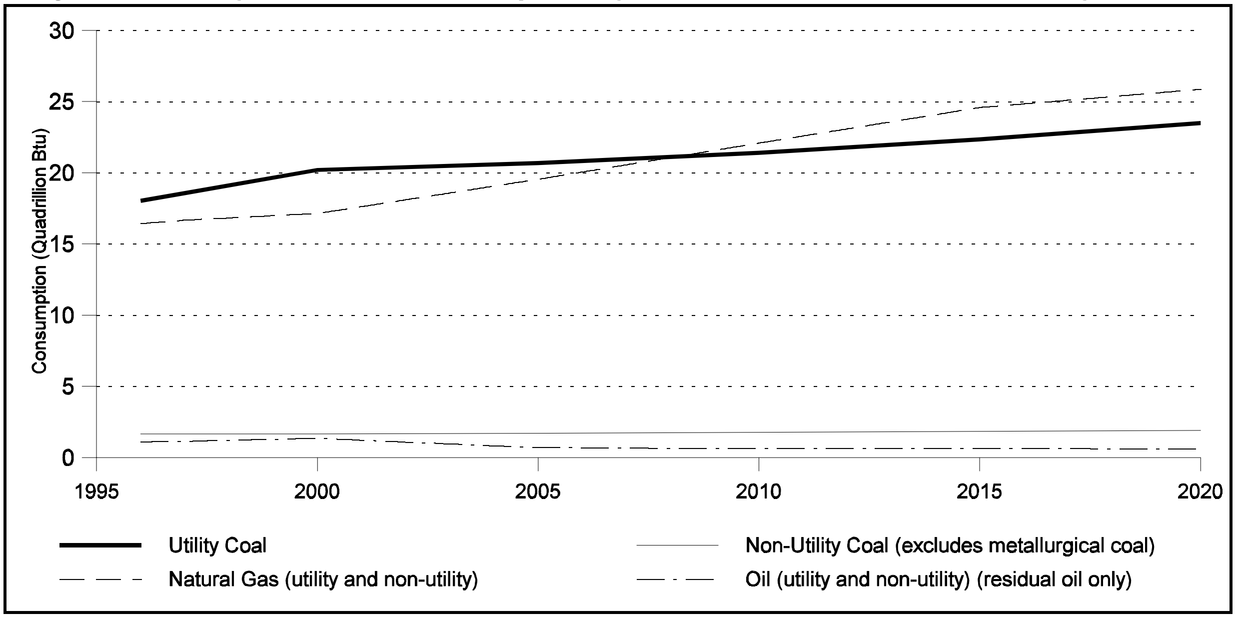
efficient technologies and relatively low growth in energy-intensive industries. In this sector, modest growth in coal use for boiler fuel is expected, with more significant growth in oil and natural gas consumption. Slow growth is expected in the commercial sector due to increased efficiency standards and declining growth in commercial floor space compared to previous decades. The relative share of individual fossil fuels is not expected to change dramatically for commercial uses (EIA, 1998a).

Based on the trends discussed above, Figure 2-4 adapts EIA data to the sectors discussed in this report. Figure 2-4 shows expected trends in FFC for each sector. Note that for oil, Figure 2-4 shows residual oil use only, since this is expected to account for nearly all oil combustion waste generation. Forecasts for 1997 through 2020 show the following:

- A moderate increase in the consumption of coal by utilities (26 percent)
- A less significant increase in the consumption of coal by non-utilities (16 percent)
- A decline in the consumption of residual oil by utilities and non-utilities (13 percent)
- A large increase in the consumption of natural gas by utilities and non-utilities combined (55 percent).

Separate forecasts are not available for the fluidized bed combustion sector. Most of the use of this technology is reflected in the consumption of coal by utilities and non-utilities. Because of the fuel flexibility, efficiency, and emissions characteristics of fluidized bed combustion units, EPA projects that use of the technology has the potential to increase at a rate greater than that of conventional coal combustion. The potential impacts of these changes in fuel consumption on waste generation are discussed in appropriate chapters of this study.

Figure 2-4. Projected Fuel Consumption by Fossil Fuel Combustion Industry Sectors



Source: EIA, 1998a, Appendix A

2.3 ENVIRONMENTAL JUSTICE

In addition to the eight study factors specifically identified in Section 8002(n) of RCRA, EPA is interested in determining whether there are environmental justice issues associated with the management of the remaining wastes from FFC. The Agency's risk modeling results indicate that subsistence farmers and their children may face potential health risks from the management of FFC wastes. The prospect that subsistence farmers may be of low-income or minority status suggests that there might be environmental justice issues associated with FFC waste management. Subsistence farmers, however, are hypothetical, highly exposed receptors modeled as part of the above-ground multimedia risk assessment. The prevalence of subsistence farming around existing FFC sites is not known. The Agency is interested in receiving additional information regarding the extent to which subsistence farming actually occurs near these facilities. EPA also is interested in learning of concerns related to environmental justice (i.e., the fair treatment of people of all cultures, incomes, and educational levels with respect to environmental hazards) associated with the management of FFC wastes.

3.0 COMANAGED WASTES AT COAL-FIRED UTILITIES

In its 1993 Regulatory Determination (58 FR 42466, 8/9/93), EPA retained the exclusion from hazardous waste regulation under Subtitle C of the Resource Conservation and Recovery Act (RCRA) for four large-volume coal combustion wastes from utilities and independent power producers when managed alone. These wastes are fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) wastes. These four large-volume utility coal combustion wastes (UCCWs) are relevant for purposes of this study when they are comanaged with low-volume combustion wastes. Comanagement occurs when a waste management unit receives both large-volume UCCWs and other wastes that are generated ancillary to, but as a necessary part of, the combustion and power generation processes. These other wastes are termed "low-volume" wastes to distinguish them from the four high-volume UCCWs. Chapter 3 focuses on these low-volume combustion wastes and the practice of comanaging these wastes with large-volume UCCWs. This chapter also considers wastes from the combustion of mixtures of coal and other fuels ("coburning") by utilities.

SECTOR OVERVIEW

EPA described the coal-fired utility sector in great detail in the 1988 Report to Congress. Coal remains the primary fossil fuel used by electric utilities in the United States. In 1997, coal accounted for more than half of the electricity generated in the United States (EIA, 1997e). The Edison Electric Institute Power Statistics Database (EEI, 1994) identifies 440 coal-fired utility power plants in the United States operating more than 1,200 individual boilers. As discussed in Chapter 2, EPA expects little increase in coal-fired generating capacity through the year 2010. Some growth in coal consumption by utilities is expected due to increased utilization of existing generating capacity (EIA, 1998).

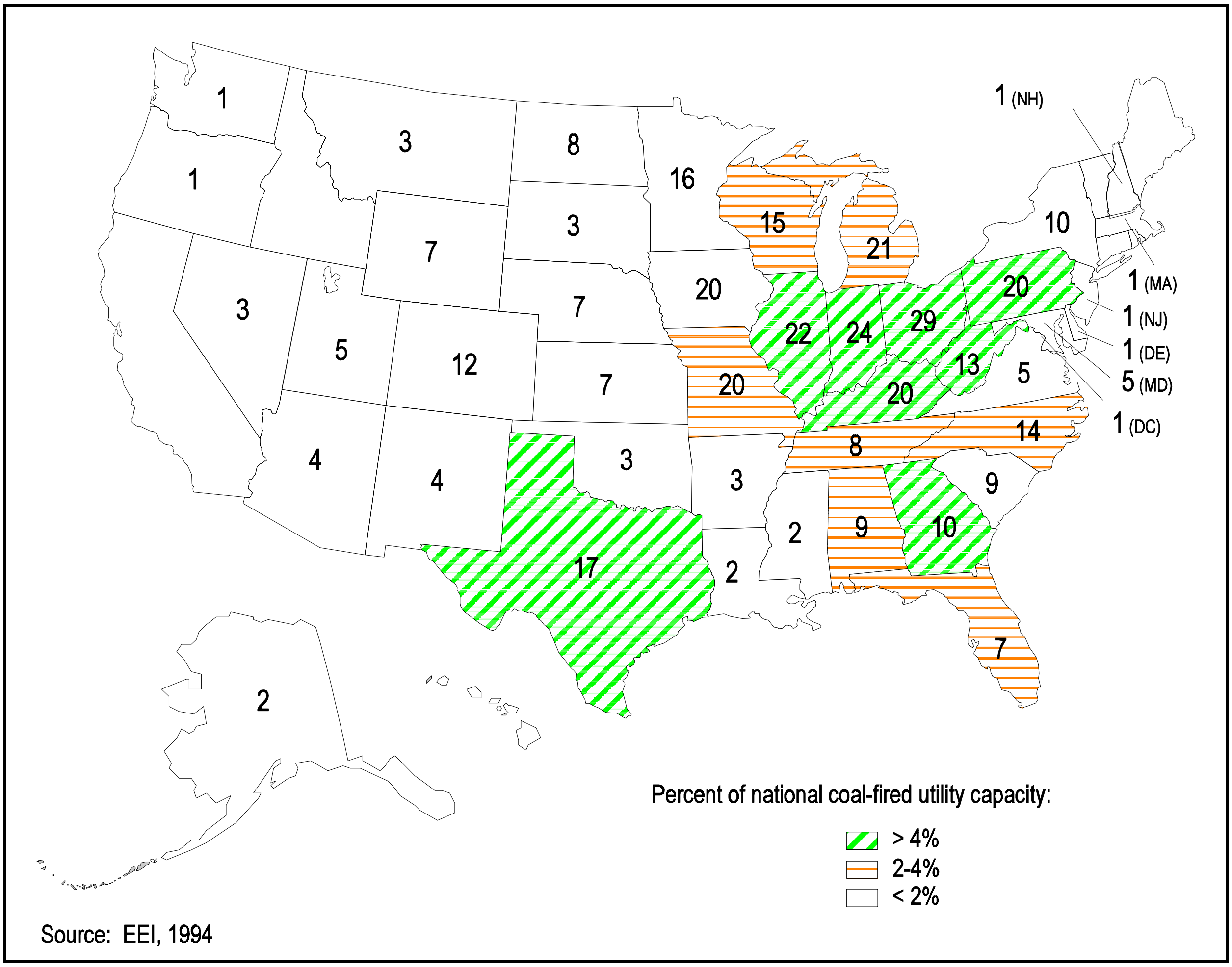
As shown in Figure 3-1, the electrical generating capacity of coal-fired utilities is concentrated in the Northeast and Midwest. While the largest numbers of facilities are located in these regions, coal-fired utility power plants are found in nearly every state. Within states, facility sites vary from urban to rural. Because of the large volume of waste generated, onsite waste management is typical. As discussed in detail in Section 3.3, comanagement is practiced at the majority of coal-fired utilities. Therefore, the geographic distribution of power plants presented in Figure 3-1 also is generally descriptive of the universe of comanaged waste sites that are the subject of this study.

3.1 WASTE GENERATION

Coal-fired utilities may generate as many as four large-volume UCCWs and a variety of low-volume wastes. The generation of large-volume UCCWs depends upon boiler technology (see Section 3.1.1), air pollution control technology (see Section 3.1.2), and fuel type (see Section 3.1.3). Large-volume UCCWs include:

- **Fly ash.** The uncombusted material carried out of the boiler along with the flue gases.
- **Bottom ash.** Uncombusted material that settles to the bottom of the boiler. Bottom ash does not melt and, therefore, remains in the form of unconsolidated ash.
- **Boiler slag.** Uncombusted material that settles to the bottom of the boiler. Slag, unlike bottom ash, forms when operating temperatures exceed ash fusion temperature and remains in a molten state until it is drained from the boiler bottom.
- **Flue gas desulfurization waste.** Waste produced during the process of removing sulfur oxide gases from the flue gases.

Figure 3-1. Number of Coal-Fired Utility Power Plants by State



Low-volume wastes are generated as a result of supporting processes (see Section 3.1.4) that are ancillary to, but a necessary part of, the combustion and power generation processes. Low-volume wastes include the following:

- **Coal pile runoff.** Runoff and drainage produced by precipitation falling on coal storage areas.

- **Coal mill rejects/pyrites.** Waste produced by onsite processing of coal prior to use.

- **Boiler blowdown.** Waste continuously or intermittently removed from boilers that recirculate water to maintain water quality.

- **Cooling tower blowdown and sludge.** Wastes removed periodically from recirculating cooling tower systems to maintain water quality.

- **Water treatment sludge.** Wastes resulting from treatment of makeup water for the steam cycle or for non-contact cooling. Treatment processes resulting in sludge generation may include settling, flocculation, softening, filtration, and reverse osmosis.

- **Regeneration waste streams.** Wastes resulting from periodic cleaning and regeneration of ion exchange beds used to remove mineral salts from boiler makeup water.

- **Air heater and precipitator washwater.** Wastes resulting from the periodic cleaning of the outside (fireside) of heat exchanging surfaces (i.e., the side exposed to hot combustion products).

- **Boiler chemical cleaning waste.** Wastes resulting from periodic cleaning of the inside (waterside) of boiler tubes with chemical solutions.

- **Floor and yard drains and sumps.** Wastewaters collected by drains and sumps, including precipitation runoff, piping and equipment leakage, and wash water.

- **Laboratory wastes.** Wastes generated in small quantities during routine analysis of coal, intake water, wastes, and other samples at a plant site.

- **Wastewater treatment sludge.** Sludge generated from the treatment in settling basins or other treatment facilities of any or all of the liquid waste streams described above.

Table 3-1 reports the quantity of each large-volume UCCW generated in 1997. The total quantity generated has increased steadily over the last decade (ACAA, 1996b; ACAA, 1998). Projected future increases in the consumption of coal by utilities (see Chapter 2) also are expected to result in increases in ash generation, albeit at a slower rate than in past decades.

The relative contribution of each waste type has changed over time. For example, since 1994, the quantity of boiler slag has decreased, while the quantity of FGD waste has increased dramatically (ACAA, 1996b; ACAA, 1998). These changes in relative share are likely due to changes in use of combustion technology, fuel, and pollution control technology. Each of these factors is discussed in greater detail below. The increase in FGD waste generation has been driven, in part, by the requirements of Title IV of the Clean Air Act (see Section 3.5). Recent and forthcoming regulatory developments (see Section 3.5) are expected to result in continued increases in the generation of FGD waste.

Table 3-1. Total Generation of Large-Volume Utility Coal Combustion Waste (UCCW)

UCCW Type	Tons Generated in 1997	Percent
Fly Ash	60,264,791	57%
Bottom Ash	16,904,663	16%
Boiler Slag	2,741,614	3%
FGD Waste	25,163,394	24%
Total	**105,074,462**	**100%**
Source: ACAA, 1998		

Table 3-2 lists typical facility-level generation rates for those low-volume wastes for which data are available. No comprehensive data exist on the total quantities of low-volume wastes generated in the United States. For purposes of this study, however, the total quantities *generated* are less significant than the quantities that are *comanaged* with large-volume UCCWs. Section 3.3 presents the available data on the quantities of waste comanaged and the frequency with which comanagement occurs.

Table 3-2. Low-Volume Waste Generation Rates at Coal-Fired Utilities

Low-Volume Waste	Typical Generation Rate
Coal Pile Runoff	Variable depending on rainfall
Coal Mill Rejects	7.5 to 12 tons per year per megawatt capacity (plants burning high-sulfur eastern coal)
Boiler Blowdown	0.1 to 1 percent of steam flow; 148 to 290 gallons per day per megawatt (recirculating steam systems only)
Cooling Tower Blowdown and Sludge	20 to 65 percent of cooling water flow; 1 to 30 gallons per day per megawatt (recirculating cooling systems only)
Water Treatment Sludge	Variable depending on treatment technology and water intake rates
Regeneration Waste Streams	40 to 104 gallons per day per megawatt
Air Heater and Precipitator Washwater (includes other fireside washwaters)	3 to 18 gallons per day per megawatt capacity
Boiler Chemical Cleaning Waste	125 gallons per megawatt, once every 2 to 5 years
Floor and Yard Drains and Sumps, Laboratory Wastes	30 to 100 gallons per day per megawatt
Wastewater Treatment Sludge	Variable depending on treatment technology and discharge rates
Sources: EPA, 1992, 1996; EPRI, 1997b; VDEQ, 1994	

3.1.1 Boiler Technology

The quantities of ash and slag generated depend in part on the combustion technology used. Currently, three conventional technologies for coal combustion are in use: pulverized coal (PC) boilers, stokers, and cyclones. All three conventional technologies involve combustion of coal in a boiler to heat water and produce steam. The steam is then used to generate electricity; in some cases, a portion of the steam may be used to provide heat. The three conventional technologies differ in design, particularly in the type and the size of the coal particle to be burned, fuel delivery mechanisms, and the combustion conditions inside the boiler furnace. The 1988 Report to Congress described each of these technologies in detail. Box 3-1 provides an overview description of these technologies and their waste generation implications.

Figure 3-2 shows how combustion technology affects the distribution of ash and slag.

Table 3-3 shows how the capacity of utility conventional coal combustion is distributed among boiler technologies. Because of their efficiency, PC boilers are the most common technology used by utilities. PC technology is well suited to large capacity applications where high efficiency is desired. The dominance of PC technology contributes to the large percentage of fly ash generated by utilities.

EPA is aware that there are other emerging technologies for combustion coal and other fossil fuels (for example, pressurized fluidized bed combustion, discussed briefly in Chapter 5) that may have different effects on waste generation and characteristics. Because of data availability issues, however, this chapter focuses on technologies in current commercial application.

Box 3-1. Conventional Coal Combustion Technologies

Pulverized Coal (PC) Boilers. PC boilers, also known as pulverizers, burn finely ground coal suspended in air. Because of the large surface area created by pulverizing the coal and the air turbulence created in PC boilers, the coal burns very efficiently and completely. The efficiency of combustion in a PC boiler affects the relative quantity of waste generated. These boilers generally achieve more complete combustion of coal constituents than do stokers. As a result, there is less unburned carbon in PC boiler ash and, in turn, a lower volume of waste generated, all else being equal.

Because of the small fuel size and the suspended combustion process, most of the ash remaining after combustion in a PC boiler is entrained in the furnace exit gas, becoming fly ash. The remainder of ash falls to the bottom of the furnace as bottom ash. In most pulverizers, referred to as dry-bottom furnaces, bottom ash remains in a dry, free-flowing ash form. Pulverizers burning coal with lower ash fusion temperatures, however, are designed as wet-bottom or slag-tap furnaces. In these units, bottom ash flows out of the furnace in molten form and cools into a slag. The proportion of bottom ash generated is greater in wet-bottom designs.

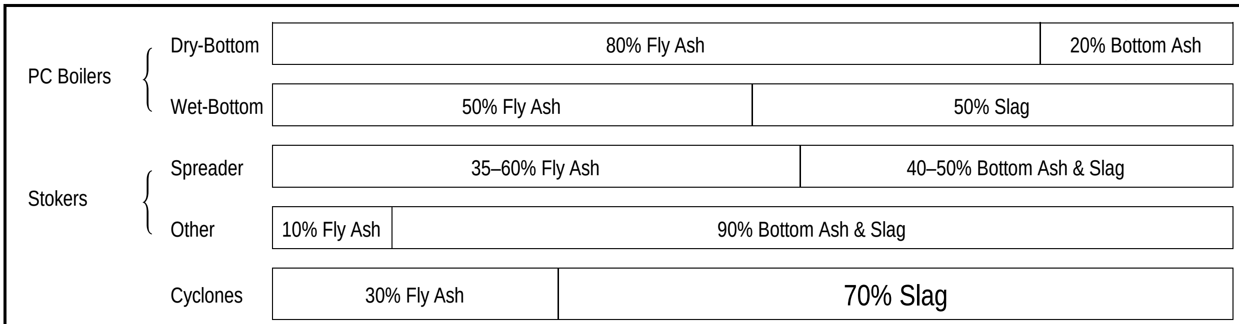
Stokers. Stoker technology feeds coal mechanically onto a grate within a furnace. Stoker feed and grate systems include a variety of designs, with the three major categories being underfeed, overfeed (or mass fed), and spreader stokers. The categories differ in the location and method of coal feeding and the design of the grate (moving, vibrating, or stationary).

Spreader stokers, which are the most common type, generate 40 to 65 percent bottom ash. The bottom ash may be a free-flowing ash or a fused clinker. Fly ash comprises the remaining 35 to 60 percent of spreader stoker waste. By comparison, overfeed and underfeed stokers do not incorporate suspension burning and have lower air velocities than spreader stokers. Therefore, they generate a lower proportion of fly ash, about 10 percent. The bottom ash from overfeed stokers can range from free-flowing ash to fused slag, while that from underfeed stokers is typically clinker or slag.

Cyclones. Cyclones burn crushed coal in a horizontal cylindrical barrel attached to the side of the boiler furnace. The cyclone design was developed to burn low ash-fusion temperature coals (i.e., slagging coals) without the need for pulverization and with slightly more flexibility in fuel feed characteristics than pulverizers. This technology creates a cyclone-like air circulation pattern that causes smaller particles to burn in suspension, while larger particles adhere to a molten layer of slag that forms on the barrel walls. Because they are designed specifically to generate a layer of molten slag, most of the waste generated by cyclones is in this form. Molten slag flows out of the cyclone barrel through a slag tap and through the furnace bottom where it typically is cooled in a tank.

Sources: CIBO, 1997c; Stultz and Kitto, 1992; Elliott, 1989

Figure 3-2. Approximate Ash Distribution by Coal Combustion Technology



Sources: CIBO, 1996c; Stultz and Kitto, 1992; and Elliot, 1989

Table 3-3. Distribution of Utility Conventional Coal Combustion Technologies

Combustion Technology	Number of Boilers	Capacity (megawatts equivalent)	Percent of Capacity
Pulverized Coal Boilers	1,068	294,035	92%
Stokers	94	1,077	<1%
Cyclones	89	25,727	8%
Total	**1,251**	**320,839**	**100%**
Source: EEI, 1994			

3.1.2 Air Pollution Control Technologies

Air pollution control (APC) technologies used to meet the needs of coal-combustion facilities may be broadly categorized as particulate controls and flue gas controls. The technologies of most relevance in the latter category are those for control of sulfur oxide emissions. The capture of fly ash is governed by the particulate control technology used—fly ash leaving the boiler must be removed from the gas stream in which it is entrained or it will be released to the atmosphere. When high sulfur coal is burned, utilities sometimes apply desulfurization technologies to remove sulfur dioxide from the flue gas to meet Clean Air Act requirements (see Section 3.5). The 1988 Report to Congress described both particulate control and desulfurization technologies in detail. Box 3-2 provides an overview description of these technologies.

Figure 3-3 shows the frequency with which coal-fired utilities utilize each type of APC technology. Overall, nearly all coal-fired utilities incorporate some type of particulate control, primarily because this is the most economical way to meet air quality regulations (see Section 3.5). ESPs are most common because this is the primary APC technology used at PC boilers. Mechanical collectors are most common for stokers, which generate the larger fly ash particles for which mechanical collection is efficient. Stokers and some other units sometimes use combination systems in which a mechanical collector is followed by an ESP or fabric filter. The types of APC technologies used have high removal efficiencies, as discussed in Box 3-2. The prevalence of particulate control, combined with these high removal efficiencies, results in a high percentage of fly ash capture at coal-fired utilities.

Desulfurization technology is not as common as particulate control but still is prevalent enough that a significant quantity of FGD waste is generated. The percentages shown in Figure 3-3 are based on 1994 data. Since that time, several large facilities have added desulfurization units in response to Title IV of the Clean Air Act (see Section 3.5), contributing to recent increases in FGD waste generation. Recent and forthcoming regulatory developments (see Section 3.5) are expected to result in increased use of FGD technology and an associated increase in quantities of FGD waste. These developments also are expected to increase the use of low sulfur coal, discussed in the next section.

3.1.3 Fuel Types

Coal burned by utilities in the United States is classified by rank: anthracite, bituminous, subbituminous, and lignite. These ranks reflect the degree of metamorphism of the coal and typically correspond to the geologic age of the coal deposit and to the heating value of the coal. Anthracite coal is the oldest rank and has the highest heating value, while lignite is the youngest and has the lowest heating value (Stultz and Kitto, 1992). Table 3-4 shows the usage of each rank by utilities in 1997, along with typical ash content. The quantity of ash and slag generated is affected by the ash content of the fuel. Ash content is, in part, determined by the rank of the coal.

Box 3-2. Air Pollution Control Technologies

Particulate Control Technologies

Electrostatic Precipitators (ESPs). ESPs are the most common particulate control technology used by coal-fired utilities. An ESP generates a high intensity electrical field that causes ash particles to acquire an electrical charge and migrate to an oppositely charged collecting surface. For typical coal-fired utilities, this process results in a collection efficiency of greater than 99 percent.

Fabric Filters. Fabric filters, also known as baghouses, capture ash as the exit gas passes through a series of porous filter bags. Baghouses have an efficiency of greater than 99 percent.

Mechanical Collectors. Mechanical collectors, most commonly known as cyclones or multicyclones, force a cyclonic flow of the exit gas. This flow causes ash particle to be thrown against the walls of the collector and drop out of the gas. Cyclones are most effective for larger particles; collection efficiency drops well below 90 percent for the smallest particles.

Scrubbers. Wet scrubbers are the least common particulate control technology. In scrubbers, water is used to trap particulates entrained in the flue gas. Scrubbers can collect large particles at efficiencies greater than 99 percent, but efficiency may be less than 50 percent for particles smaller than 1 or 2 micrometers. Scrubbers also demand high energy consumption for high efficiency and produce a wet effluent to be disposed.

Desulfurization Technologies

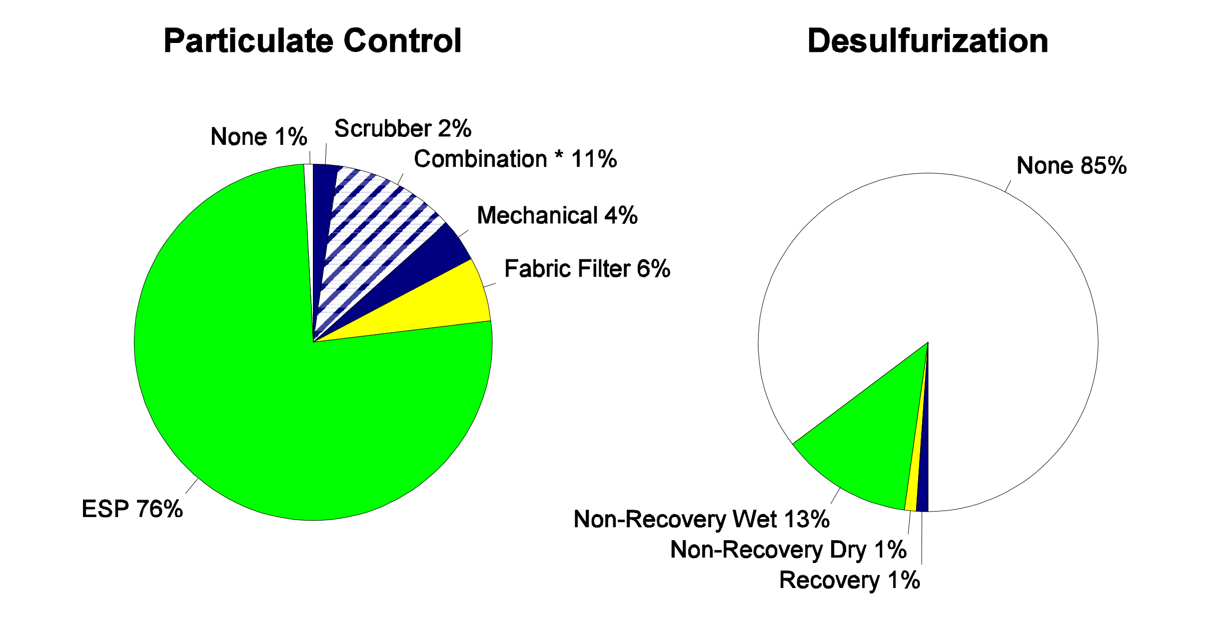
Desulfurization technologies are categorized as recovery systems and non-recovery systems. Recovery systems are those that produce FGD wastes that are suitable for reuse, for example, in wallboard (see Section 3.6.2 for discussion of use in wallboard). Non-recovery systems produce FGD waste that must be disposed. Non-recovery systems are further classified as wet and dry systems. Wet systems scrub and saturate flue gas with a slurry of water and a sorbent (usually lime or limestone) that reacts to remove sulfur from the gas in the form of a sludge. Dry systems typically contact flue gas with a sorbent slurry in a spray dryer without saturating the gas with water. The dry reaction product is then collected along with fly ash in a fabric filter or ESP. Wet systems are more effective at removing sulfur dioxide and, therefore, are used by a larger proportion of generators. However, because of their use of liquids, wet systems produce more waste than do dry systems.

Sources: Stultz and Kitto, 1992; EPA, 1998c; Elliott, 1989; DOE, 1993

In addition to coal rank, ash content depends on the specific coal producing region, mine, seam, and production method. To reduce maintenance and waste management costs and to meet particulate emissions standards, utilities have, over time, increased their use of coal with a lower ash content. Over the past two decades, the average ash content of coal used by U.S. utilities has decreased consistently, from 13.5 percent in 1975 (DOE, 1993) to 9.22 percent in 1996 (EIA, 1996f). This reduction corresponds to the increased use of coal from Wyoming, which has a relatively low ash content (EIA, 1996f). In addition, coal characteristics can be, and often are, changed prior to combustion through cleaning. Approximately 70 percent of coal used by electric utilities is cleaned in some way. In some cases, these cleaning processes can reduce ash content by as much as 50 to 70 percent (Stultz and Kitto, 1992). In part because of the trend toward lower ash content, the increase in ash generation over time has not kept pace with the general increase in coal use.

The type of coal burned also affects the distribution of the ash and slag waste streams generated by combustion. For example, because softer lignite coals tend to have a lower ash fusion temperature, they tend to generate boiler slag rather than bottom ash.

Figure 3-3. Air Pollution Control Technologies Used at Coal-Fired Utilities



* Mechanical collector followed by fabric filter or ESP.
Source: EEI, 1994

Table 3-4. Ash Content and Fuel Usage by Coal-Fired Utilities

Coal Class	Ash Content	Utility Usage in 1997 (1,000 tons)	Percent of Total Usage
Anthracite	4 to 19%	1,013	< 1%
Bituminous	3 to 32%	821,823	91%
Subbituminous	3 to 16%		
Lignite	4 to 19%	77,524	9%
Total		**900,360**	**100%**
Sources: Ash content CIBO, 1997c; fuel usage EIA, 1998b			

Because FGD waste is generated in removing sulfur oxide gases from the flue gas stream, the amount of FGD waste generated depends on the sulfur content rather than the ash content of the fuel. Furthermore, when utilities burn low sulfur coal, they often can meet regulatory requirements without the application of desulfurization technology and, therefore, without generating FGD waste.

The sulfur content of coal varies geographically across the United States. Some Iowa coals contain as much as 8 percent sulfur by weight, while western coal deposits (e.g., Montana and Wyoming) average less than 1 percent sulfur (Stultz and Kitto, 1992). The sulfur content of coal also can be reduced through cleaning to remove pyrites (iron sulfide minerals that are oxidized to produce sulfur oxide gases during the combustion process). The average sulfur content of coal burned by electric utilities in 1996 was just over 1 percent by weight but ranged from more than 3 percent in states relying on Midwestern coal to less than 0.5 percent in some western states (EIA, 1996f). A number of utilities recently have switched to low-sulfur coal in response to regulatory requirements (EIA, 1997f). Recent and forthcoming regulatory developments (see Section 3.5) are expected to result in increased use of low-sulfur coal in the future.

In addition to coal, coal-fired utilities sometimes combust other fuels in combination with coal. This practice of mixing fuels is known as "coburning." Wastes from mixtures of coal and other fuels containing up to 50 percent other fuels are considered remaining wastes subject to this study. The types of materials that have been coburned in such mixtures include (EPRI, 1997m; IEA, 1996):

- Agricultural refuse
- Auto shredder fluff
- Bark and other wood
- Biomass
- Boiler cleaning wastes
- Contaminated soils and other wastes from manufactured gas plant sites
- Mill rejects
- Oil combustion wastes
- Paper mill sludges
- Peat
- Petroleum coke and petroleum coke/limestone blends
- Railroad ties
- Refuse derived fuel
- Regeneration waste streams
- Sewage sludge
- Straw
- Tire derived fuel
- Used oil.

In addition, EPA is aware that ongoing technological advancement has developed the potential for combusting other coal-fuel mixtures and other non-coal fossil fuels (for example, Orimulsion fuel, discussed briefly in Chapter 6). Because of data availability issues, however, this chapter focuses on fuels burned in current commercial application.

3.1.4 Supporting Processes

The generation of low-volume wastes primarily is associated with processes that support the combustion process or make use of the products of combustion. These supporting and enabling processes accompany combustion at all coal-fired utilities. The following common supporting processes can be significant with respect to low-volume waste generation:

- Coal storage
- Coal processing
- Steam generation
- Cooling
- Water treatment
- Cleaning and maintenance
- Wastewater treatment.

The paragraphs below describe these processes and their waste generation aspects. The large number and wide variety of low-volume wastes generated at coal-fired utilities correspond to the variety of these processes.

Coal Storage

The low-volume waste, coal pile runoff, is associated with coal storage. The coal utilized at utilities is usually stockpiled onsite to ensure an adequate supply. The amount of fuel stored is generally proportional to the capacity of the combustion process. Particularly for large capacity utilities, the amount required may be quite large. In fact, regulations for some public utilities require that a minimum 60- to 90-day supply be stored at the plant (Stultz and Kitto, 1992). A 90-day reserve of coal amounts to 600 to 1,800 cubic meters of storage capacity per megawatt plant capacity (EPA, 1996).

Typically, storage of such large volumes of coal is in open stockpiles, as this has proven to be the most economically efficient storage method. These piles usually are uncovered and exposed to precipitation, resulting in the potential intermittent generation of runoff. Coal pile runoff typically must be collected to prevent contamination of the local environment. The characteristics of the runoff depend upon the type and age of the coal, the pile shape, and the precipitation characteristics. Waste generation rates vary depending on the footprint of the pile (i.e., the basal area) and the local precipitation.

Coal Processing

Coal usually is delivered to utilities in large pieces and must, at a minimum, be reduced in size prior to combustion. The extent and nature of additional processing will depend on the desire of the user to reduce ash and sulfur content and upon the size and feed characteristics requirements of the combustion technology. Coal processing results in the removal of various materials, commonly termed coal mill rejects, that may include rocks, metal fragments, hard coal, and other minerals, such as pyrites. The quantity of these low-volume wastes will be highly variable depending on the coal source and processing technology (EPRI, 1997b). An important component of the rejects wastestream is pyrite, a hard iron sulfide (FeS_2). As will be discussed in subsequent sections, these pyrites are associated with acid generation concerns within waste management areas, often requiring isolation from water and oxygen in order to minimize those concerns.

Steam Generation

The steam generation process can entail the generation of the low-volume waste called boiler blowdown. All of the fossil fuel combustion technologies described in this report are used to heat water and generate steam, which in turn is used to generate electricity. In the steam generation process, products of combustion often travel from the boiler into a series of other components, such as superheaters, economizers, and/or air heaters. There are a variety of boiler and system designs; all serve the purpose of absorbing heat from combustion and converting water into steam (Stultz and Kitto, 1992).

After the high-temperature, high-pressure steam generated in the boiler components is used to generate electricity or for other industrial use, a large volume of low-pressure “dead” steam remains. This steam typically is condensed into water to be recirculated back through the boiler in a closed loop (EPA, 1996). Dissolved solids and suspended salts in the boiler water increase with continued circulation through the steam cycle. To prevent excessive buildup of these constituents, some water is removed, either periodically or continuously, and replaced with purified feed water (EPRI, 1997b). This bleed waste stream, commonly referred to as boiler blowdown, may contain contaminants built up during the steam cycle, precipitated solids, corrosion products, and chemical additives. The volume of boiler blowdown can range from 0.1 to 10 percent of the total steam flow, depending on boiler design.

A few plants (less than 10 percent of the coal-fired utility population, according to the 1994 Edison Electric Institute [EEI] database) do not recirculate boiler water, instead using a once-through, non-recirculating steam system. These systems do not generate boiler blowdown (EPA, 1996).

Cooling

Cooling processes can result in the generation of low-volume wastes, such as cooling tower blowdown and sludge.[1] In plants with a recirculating steam system, condensation of "dead" steam occurs by transferring heat to cooling water. This cooling water does not directly contact the steam but takes on the waste heat by flowing through a heat exchanger called a condenser. This process requires a constant flow of large volumes of chilled cooling water, which itself may be supplied in either a once-through or recirculating system. More than 70 percent of coal-fired utilities reporting cooling system information in the 1994 EEI database use recirculating cooling systems. To control bacterial growth, utilities sometimes add biocides, such as chlorine compounds, to their cooling water systems. The use of chlorine compounds can cause toxic chlorinated organic byproducts to form in discharges from cooling water systems. Because of concerns about these compounds, there has been an increasing trend in the use of alternative biocides (e.g., bromine and nonoxidizing biocides, such as quaternary ammonium compounds and bromonitrostyrene) that do not form highly toxic byproducts (EPA, 1996).

In recirculating cooling water systems, heat picked up in the condenser must be transferred to the atmosphere by means of cooling towers, cooling ponds, or spray canals before the water is returned to the system. Cooling towers and spray canals or ponds promote evaporative cooling. As a result, some water must be removed and replaced with fresh water to prevent impurities from becoming concentrated in the recirculating cooling system. The quantity removed can range from 20 to 65 percent of the cooling water flow rate (EPA, 1996). The water removed is referred to as cooling tower blowdown. Also, over time, solids can collect in the bottom of cooling towers. This cooling tower sludge is periodically removed and disposed (EPRI, 1997b).

Water Treatment

Treatment of water prior to use in a fossil fuel combustion system may generate low-volume wastes, including treatment sludges and regeneration wastes. Losses of water from within the steam cycle typically require that operators use makeup water in the system. In addition, closed-loop, non-contact cooling systems may require makeup water. The makeup water usually must be treated to remove dissolved gases, suspended solids, and dissolved chemical salts that would negatively impact the efficiency of the operation. Required treatment processes may include clarification, filtration, reverse osmosis, and/or lime softening. These operations will usually generate water treatment wastes, such as sludges. The characteristics of this treatment sludge will depend upon the source water characteristics and the treatment process used.

Another type of makeup water treatment is the use of an ion exchange process to remove mineral salts. The ion exchange beds are a resin that requires periodic rinsing with an acidic or basic solution to regenerate the resin (i.e., remobilize and backflush the contaminants removed by the resin). These waste

[1] Large-volume UCCWs transported/mixed with certain non-contact cooling waters fell within the scope of EPA's 1993 Regulatory Determination (58 FR 42466). Because of the continuous use of these process waters, the Agency does not consider them wastes and they are outside the scope of this study. However, discussion of the generation and characteristics of these waters is relevant because effluent and sludge from treatment of these and other plant wastewaters do fall within the definition of low-volume waste.

streams are commonly referred to as regenerant solutions (EPA, 1996). Furthermore, when regeneration of the resin is no longer possible, the spent resin is disposed and may be comanaged (EPRI, 1997b).

Cleaning and Maintenance

Cleaning processes intermittently generate low-volume wastes, including air heater and precipitator washwater and boiler chemical cleaning waste. The heat exchanging surfaces of steam generating systems require periodic cleaning to remove deposits and maintain efficiency. The fireside surfaces (i.e., the side exposed to hot combustion products) of components, including boilers, superheaters, economizers, and precipitators, collect ash, dust, and corrosion products. These surfaces are cleaned using steam, water, or an alkaline solution. Hardened deposits may require mechanical removal (EPRI, 1997b). The fireside surfaces of air heaters (which use flue gases to preheat combustion input air) also collect ash and dust. These surfaces are cleaned with water or an alkaline solution, often more frequently than other fireside surfaces (EPA, 1996). The resulting washwaters are low-volume wastes.

The waterside surfaces of boiler tubes collect scale in the form of precipitated salts and corrosion products. Chemical solutions must be used infrequently to remove this scale and prevent restriction of water flow. Depending on the boiler contaminants present, cleaning solutions may include alkalis, acids, and chelants. There is some evidence of a trend by utilities toward using less toxic cleaning solutions. For example, one utility reported switching from hydrochloric acid to citric acid in 1995 (EPRI, 1992). The waste resulting from chemical cleaning is commonly termed boiler chemical cleaning waste. Both boiler chemical cleaning wastes and fireside cleaning wastes are sometimes termed metal cleaning wastes (EPRI, 1997b).

Wastewater Treatment

At fossil fuel combustion facilities, a variety of liquid streams (including low-volume wastes, ash handling waters, and site runoff) may require treatment prior to discharge. Required treatment processes will vary depending on the combination of streams treated and on discharge requirements. These operations will usually generate treatment wastes, such as sludges. The characteristics of this treatment sludge will depend upon the source water characteristics and the treatment process used.

3.2 WASTE CHARACTERISTICS

By definition, comanaged wastes consist of one or more low-volume wastes in combination with one or more large-volume UCCWs. Therefore, this section briefly describes the characteristics of low-volume wastes and UCCWs as generated prior to discussing the characteristics of comanaged wastes. The section concludes with a discussion of the available data on wastes from coburning by utilities.

3.2.1 Large-Volume and Low-Volume Utility Coal Combustion Wastes as Generated

As part of its 1988 Report to Congress (EPA, 1988) and 1993 Regulatory Determination (58 FR 42466), EPA presented substantial data characterizing large-volume UCCWs and certain low-volume wastes. Detailed characterization is not included here. Instead, this section presents an overview of earlier characterization efforts, along with analyses based on more recent data for selected wastes.

Physical and Chemical Characteristics

Each of the large-volume wastes can exist as a dry solid or wet slurry, depending on collection and management technology. Other physical characteristics vary from waste type to waste type. Fly ash is typically generated and collected as a solid but may be transported by sluicing. This type of waste consists primarily of particles between 5 and 100 microns (EPA, 1988). Fly ash typically has a round shape resulting from the high temperatures used in a pulverized coal boiler (CIBO, 1997c). Bottom ash and slag can be generated from a wet-bottom or dry-bottom pulverized-coal boiler. The bottom ash collected from a dry-bottom system can be transported in a dry state or sluiced. Bottom ash and boiler slag consist of larger particles than fly ash, ranging from 0.1 millimeter (100 microns) to 10 millimeters in diameter (EPA, 1988). Bottom ash has a coarse angular structure, while boiler slag consists of angular particles with a glassy appearance (CIBO, 1997c). FGD waste can be generated from a dry sorbent system or a wet scrubber system. Wet systems generate waste with slightly smaller particle size (0.001 to 0.05 millimeters) than dry systems (0.002 to 0.074 millimeters). Wet systems also generate a filter cake or similar wet solid (16 to 43 percent moisture), while waste from dry systems contains no liquids (USDA, 1998).

Oxides of silicon, iron, aluminum, and calcium compose 95 percent of the weight of both bottom and fly ash. These constituents also are present in significant quantities in boiler slag (EPA, 1988). Calcium sulfate is the principal constituent of limestone-based FGD waste. Large-volume wastes also contain trace metals. Mean concentrations of arsenic, barium, beryllium, boron, copper, and vanadium are highest in fly ash. Bottom ash has mean contaminant levels lower than fly ash for most constituents. Mean concentrations of antimony, lead, mercury, selenium, and zinc are highest in FGD waste.

Several studies have included testing of organic constituents in large-volume UCCWs, including polynuclear aromatic hydrocarbons (PAHs) and dioxins. Although an exhaustive review of organics data has not been conducted, based on available information, total and leachable organics are generally reported to be at or below analytical detection limits (EPRI, 1987; EPA, 1982).

Because low-volume wastes are generated throughout the combustion process and its ancillary activities, the characteristics of these wastes are extremely variable. EPA does not have comprehensive data characterizing every type of low-volume waste that might be comanaged with large-volume coal combustion wastes. Table 3-5 presents the principal physical and chemical characteristics of several major types of low-volume waste.

EPA has identified coal mill rejects (and particularly their pyrite component) as a low-volume waste of particular concern. If mismanaged, these materials have the potential to oxidize and generate acids that could leach metals from surrounding materials to ground and surface waters. Table 3-6 presents recent characterization data for coal mill rejects.

Leaching and Hazardous Waste Characteristics

In the 1988 Report to Congress and 1993 Regulatory Determination, EPA evaluated whether large-volume wastes exhibited any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and toxicity. EPA determined that large-volume UCCWs are unlikely to be corrosive, reactive, or ignitable. EPA also found that metals generally are not found in leachate above the toxicity characteristic (TC) levels. Only three metals—cadmium, chromium, and arsenic—were detected in any ash or sludge samples above the TC levels and then only infrequently. Other constituents of large-volume UCCW not on the EPA toxicity characteristic list (e.g., boron, copper, nickel, vanadium, and

Table 3-5. General Composition of Selected Low-Volume Wastes

Low-Volume Waste	Principal Physical or Chemical Characteristics
Coal Pile Runoff	Acidic or alkaline solution (depending on coal type) with uncombusted coal particles. May contain calcium, metals, silica, chloride, sulfate, and dissolved and suspended solids.
Coal Mill Rejects	Hard coal, quartz, and iron sulfides (pyrites) that cannot be ground by mills.
Boiler Blowdown	Alkaline solution of boiler feed water with low dissolved solids. May contain chlorides, sulfates, calcium and magnesium salts, precipitated solids, corrosion products, and chemical additives, such as phosphates, sodium hydroxide, sodium sulfite, hydrazine, and chelating agents.
Cooling Tower Blowdown and Sludge	Similar to makeup water, with biocides, anti-corrosives, and other additives. Sludge contains settled solids. Contaminants may include calcium and magnesium salts, metal oxides, asbestos, biofouling inhibitors, zinc, phosphonates, sulfuric acid, chlorine, wood preservatives, suspended solids, carbonates, nitrates, and sulfates.
Water Treatment Sludge	Sludge from the treatment of makeup water.
Regeneration Waste Streams and Other Water Treatment Wastes	Strong acid and base regeneration solutions, with concentrated makeup water contaminants. May contain calcium, metals, sodium, chlorides, sulfates, and organics.
Air Heater and Precipitator Washwater	Aqueous solution with suspended ash from fireside cleaning. May include a source of alkalinity for pH control. May contain metals, dissolved or suspended solids, and polynuclear hydrocarbons from soot deposits.
Boiler Chemical Cleaning Waste	Aqueous weak acid or base solution containing residual cooling system additives. May contain ammonium sulfate, ammonium carbonate, oxidizing agents, metals, hydrochloric or other acids, phosphates, fluorides, organic compounds, caustics, and silica.
Floor and Yard Drains and Runoff	Low solids aqueous waste with soil, ash, some uncombusted coal, oil and grease, and phosphates and surfactants.
Laboratory Wastes	Miscellaneous aqueous wastes expected to be represented by above. May be acidic or alkaline and may contain methylene chloride, phthalates, silica, phosphorous, hydrazine, and sodium.
Wastewater Treatment Sludge	Sludge from management of several of the above wastes.
Sources: EPA, 1988, 1996; EPRI, 1991, 1992, 1994a, 1994b, 1996a, 1996b, 1997b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, 1997l, and 1999	

zinc) were evaluated for potential risks to human health and the environment in 1988 and 1993. In particular, boron was cited as a cause of vegetative damage in the 1993 Regulatory Determination.

Based on available information and engineering judgment, EPA does not expect any low-volume waste to be ignitable, and EPA does not expect low-volume wastes other than mill rejects (potentially) to be reactive. Table 3-7 summarizes the results of this analysis. Because of the variable physical characteristics of these wastes, the data represent a combination of analysis methods: toxicity characteristic leaching procedure (TCLP) or extraction procedure (EP) leachate data for solid wastes and sludges, and measurement of dissolved analytes for aqueous wastes.

Table 3-7 shows that certain low-volume combustion wastes sometimes display the RCRA characteristics of toxicity and/or corrosivity. Specifically, boiler chemical cleaning wastes, coal pile runoff, and demineralizer regeneration wastes displayed hazardous characteristics in at least one analyzed sample. Table 3-7 shows that no samples of coal mill rejects as generated exhibited the characteristics of toxicity or corrosivity. However, EPA believes that coal mill rejects containing significant levels of

Table 3-6. Total Concentration Data for Coal Mill Rejects (ppm)

Constituent	Mean	Range
Major Constituents (maximum concentration greater than approximately 1 percent)		
Calcium	91,700	6,700–267,000
Iron	132,400	9,500–357,300
Magnesium	14,200	1,800–60,300
Manganese	8,500	100–146,100
Potassium	6,100	50–19,100
Trace Constituents		
Arsenic	104	1.50–447
Barium	370	48.0–1,070
Cadmium	3.78	3.5–9
Chromium	64.8	9–3,380*
Copper	23.5	4.5–69
Lead	18.4	4.5–121
Mercury	0.35	0.04–0.88
Nickel	48.3	9–464
Selenium	11.1	2.5–50
Silver	12.6	4.5–41
Zinc	23.05	4.5–225

* Considered to be an outlier; not included in calculation of mean
Note: Values below the detection limit were treated as one-half the detection limit.
Source: EPRI, 1999

pyrites may be reactive, due to their reactive sulfide content. Because of the low number of samples available (between 2 and 15 samples for each waste type), no attempt was made to extrapolate the frequency of RCRA characteristic exceedences to the population as a whole.

3.2.2 Comanaged Utility Coal Combustion Wastes

Physical and Chemical Characteristics

From a physical standpoint, comanaged wastes are similar to large-volume UCCWs, especially in cases where the UCCWs are managed with low-volume aqueous wastes or only small quantities of low-volume solid wastes. For example, a solid sample of comanaged ash managed under these conditions has a similar particle size and gross physical characteristics (e.g., oxides of aluminum, silicon, iron, and calcium) as the ash when generated.

Differences in physical properties between comanaged wastes and high-volume wastes can be apparent in localized areas of a waste management unit. Comanaged wastes generally show some

Table 3-7. Summary of Hazardous Waste Characteristics for Low-Volume Wastes

Low-Volume Waste	Exceedences of RCRA Characteristics
Coal pile runoff	Exceedences for cadmium, chromium, lead, selenium, and silver in one or more samples
Coal mill rejects	No exceedences; potentially reactive when significant levels of pyrites are present
Boiler blowdown	No exceedences
Cooling tower blowdown and sludge	No exceedences
Regeneration waste streams and other water treatment wastes	Exceedences for pH, chromium, and lead in one or more samples
Air heater and precipitator washwater	No exceedences
Boiler chemical cleaning waste	Exceedences for pH, chromium, and lead in one or more samples
Floor and yard drains and runoff	No exceedences
Sources: EPA, 1988; EPRI, 1991, 1992, 1994a, 1994b, 1996a, 1996b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, and 1997l	

properties of each material. For example, comanagement of fly ash in a section of a pond receiving coal pile runoff results in a mixture resembling combusted and uncombusted coal particles, while comanagement of coal mill rejects and bottom ash results in a mixture resembling a coarse angular and glassy material with oxidized iron (EPRI 1991, 1992, 1994a, 1994b, 1996a, 1996b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, and 1997l).

The chemical characteristics of comanaged wastes are dependent on the type and quantity of low- and large-volume wastes present. EPA has characterized comanaged waste using “as managed” samples from 17 comanaging utility sites. The Agency has compared the comanagement practices at these facilities to industry-wide practices as described by EPRI comanagement survey results. Based on this comparison, EPA concluded that comanagement practices at sampled sites are similar to industry-wide practices or reflect a greater degree of comanagement than at the sites in the general population. Therefore, the characterization data presented here are considered representative of the range of waste combinations that are managed by the industry.

Table 3-8 presents waste characterization data for comanaged wastes in impoundments and landfills. Of constituents of potential concern, barium, strontium, and manganese are present in the highest concentrations. These findings are similar to the characteristics of large-volume UCCWs as presented in the 1988 Report to Congress. Additionally, Table 3-8 shows that the characteristics of comanaged wastes collected from landfills and impoundments are generally within an order of magnitude of each other. A much smaller number of landfills are represented in the data, which may contribute to uncertainty in those results.

As discussed in the previous section, EPRI has provided a limited quantity of data on organic constituents in comanaged wastes. The data generally indicate that these constituents are not present at levels above detection limits. EPA evaluated the data available on the presence of dioxins and furans in comanaged wastes. Very few samples had concentrations of individual compounds above detection limits. The most toxic compound, 2,3,7,8-TCDD, was not detected in any of the 17 samples from 11

Table 3-8. Facility Average Concentrations of Trace Constituents in Comanaged Wastes (parts per million) (whole waste)*

Constituent	Managed in Surface Impoundments		Managed in Landfills	
	Mean	Range	Mean	Range
Arsenic	40	6.7–150	20	6.2–38
Barium	1,600	150–8,400	2,900	1,800–3,800
Beryllium	8.4	0.88–16	n/a	n/a
Boron	190	0.03–420	n/a	n/a
Cadmium	6	0.20–24	n/a	n/a
Chromium	85	5.7–290	50	35–78
Cobalt	29	4.7–42	n/a	n/a
Copper	78	2.2–150	105	97–120
Lead	42	5–150	17	6.5–29
Manganese	280	55–660	460	200–820
Nickel	68	1.5–160	51	33–65
Selenium	37	0.025–320	14	0.8–32
Silver	5.2	0.03–14	n/a	n/a
Thallium	27	10.6–48	n/a	n/a
Strontium	1,040	1–4,800	2,100	1,100–2,650
Vanadium	120	20–350	86	23–160
Zinc	150	17–860	84	35

*All measurements identified as below detection limit were assigned a value equal to one-half the detection limit for use in the calculations. All concentrations are facility-averaged; i.e., multiple measurements from a single site are averaged, and the resulting population of facility averages used to generate the statistics in this table.
n/a = data not available
Sources: EPRI, 1991, 1992, 1994a, 1994b, 1996a, 1996b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, and 1997l

sites. Compositing the concentrations of all compounds of interest using their respective 2,3,7,8-TCDD equivalency factors, the samples displayed 2,3,7,8-TCDD equivalent concentrations from below detection to 2.1 ng/kg (approximately one order of magnitude above typical detection limits). By comparison, a reference sample of municipal waste incinerator fly ash had a 2,3,7,8-TCDD equivalent concentration of 1,460 ng/kg (parts per trillion) (EPRI, 1998b).

Coal contains and emits low levels of naturally occurring radiation (Radian, 1988). Concentrations of radionuclides in coal vary with coal rank and origin. For example, uranium and thorium concentrations in U.S. coals range from below 0.01 parts per million (ppm) to roughly 75 ppm, based on analyses of more than 6,000 samples (EPA, 1995c). However, the geometric mean concentrations of uranium and thorium for the same sample population are 1.2 ppm and 2.2 ppm, respectively. These concentrations correspond to activities of roughly 0.41 pCi/g and 0.24 pCi/g, respectively. Because they do not volatilize, these elements generally concentrate in coal ash, such that activity levels in the ash increase relative to the radioactivity in source coal (EPA, 1989a). EPA estimates an average increase of roughly 10×, such that average activity levels for curanium and thorium are 4 pCi/g and 2.4 pCi/g, respectively.

EPA has reviewed radionuclide concentrations in coal and ash in connection with other regulatory programs (EPA 1989a, 1989b, 1995c). One of these studies examined potential exposures of worker and nearby resident to radioactivity from ash released from coal pile through wind and runoff erosion. Exposure from direct contact, inhalation, and ingestion were estimated to fall below natural background radiation exposure levels even for a worker standing on the ash pile (EPA, 1989a). In addition, EPA is currently studying coal combustion wastes as part of a larger study of naturally occurring radioactive materials (NORM). The report from this NORM study is expected to be published later in 1999. Due to the low expected risks associated with radionuclides in coal ash, and to prevent duplication of effort with the NORM study, EPA eliminated radionuclides from further consideration in this study.

Based on these characterization results, EPA concludes that metals are the class of constituents potentially of concern in comanaged wastes. Section 3.4 discusses the potential risks of metals in these wastes to human health and the environment.

Leaching and Hazardous Waste Characteristics

EPA evaluated whether comanaged waste exhibited any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and toxicity. Based on available information and professional judgment, EPA does not expect any comanaged wastes to be ignitable or reactive. To evaluate corrosivity, EPA examined pH data from pore waters (i.e., interstitial water from borings of waste managed in surface impoundments that represents leachate from the solid wastes and liquids from the comanaged liquid low-volume wastes). None of these samples exceeded the limits for corrosivity (pH less than or equal to 2 or greater than or equal to 12.5).

EPA evaluates the characteristic of toxicity using TCLP results. Examining available TCLP results for comanaged wastes, the Agency found that none of the 27 samples exhibited leachate concentrations in excess of the regulatory standard. Thus, comanaged wastes are not expected to exhibit the RCRA characteristic of toxicity.

EPA does not conclude from these TCLP results, however, that comanaged wastes are incapable of mobilizing constituents at levels of concern. Specifically, pore water (i.e., interstitial water from borings) from some comanaged wastes shows concentrations above the TCLP regulatory limits. EPA used pore waters from impoundments to represent the range of concentrations of potentially hazardous constituents mobilized in comanaged wastes. These data were used instead of TCLP data for evaluating impoundment leachate because (1) they represent actual leachate conditions at the sampled sites, and (2) a larger and more representative database exists for pore water analyses than for TCLP analyses. On the other hand, the TCLP data are believed to better represent leaching conditions at landfills than would pore water data from impoundments.

Therefore, the leachate data in Table 3-9 use pore water data to represent leachate from impoundments and TCLP data to represent leachate from landfills. To maximize the sample size, the table includes TCLP results from wastes managed in both impoundments and landfills in the column representing landfills. Evaluation of the pore water data shows that the highest concentrations of arsenic are associated with a site with significant quantities of coal mill rejects comanaged with fly and bottom ash. One other facility contributed high arsenic values, but it is not evident that mill rejects are comanaged in significant quantities at that site. No other significant effects from comanagement are evident from the data.

Table 3-9. Facility Average Leachate Concentrations for Comanaged Wastes (mg/l)

Constituent	RCRA Standard	Managed in Surface Impoundments[a]		Managed in Landfills[b]	
		Mean	Range	Mean	Range
RCRA Toxicity Constituents					
Arsenic	5.0	1.57	0.0075–9.64	0.0382	0.000875–0.236
Barium	100.0	2.1	0.001–27.4	1.06	0.114–3.63
Cadmium	1.0	0.0341	0.00099–0.250	0.00542	0.00015–0.0443
Chromium	5.0	0.175	0.00075–0.746	0.0211	0.00067–0.0589
Lead	5.0	0.0838	0.000766–0.468	0.00365	0.00106–0.00675
Mercury	0.2	0.00080	0.00080–0.00080	0.00005	0.000005–0.000118
Selenium	1.0	0.214	0.00325–1.03	0.0686	0.00483–0.440
Silver	5.0	Not calculated [c]		0.00134	0.0006–0.00225
Non-RCRA Constituents					
Aluminum	n/a	n/a	n/a	3.69	0.155–11.7
Antimony	n/a	Not calculated [c]		0.00431	0.00105–0.0125
Beryllium	n/a	Not calculated [c]		0.00151	0.00005–0.00675
Boron	n/a	n/a	n/a	3.26	0.103–9.63
Calcium	n/a	n/a	n/a	549	44.9–1,110
Cobalt	n/a	Not calculated [c]		0.00758	0.00192–0.0167
Copper	n/a	0.131	0.00085–0.67	0.0307	0.00105–0.087
Iron	n/a	n/a	n/a	1.09	0.0058–10.75
Magnesium	n/a	n/a	n/a	48.5	2.71–184
Manganese	n/a	n/a	n/a	0.766	0.0444–2.23
Nickel	n/a	0.701	0.005–8.328	0.0253	0.0066–0.0508
Potassium	n/a	n/a	n/a	5.44	2.33–10.9
Sodium	n/a	n/a	n/a	1379	1,253–1,545
Sulfate	n/a	n/a	n/a	479	14.0–2,025
Thallium	n/a	Not calculated [c]		0.00528	0.00185–0.0152
Vanadium	n/a	0.242	0.01195–0.800	0.0399	0.0054–0.122
Zinc	n/a	1.65	0.0121–2.31	0.192	0.018–1.16

[a] Leachate represented by pore water samples; i.e., the laboratory-extracted interstitial waters from borings of waste managed in surface impoundments.

[b] TCLP results for samples of waste managed in both surface impoundments and landfills.

[c] The constituent was not detected in any samples, or detected in a small number of samples, and therefore meaningful statistical values cannot be calculated.

All measurements identified as below detection limit were assigned a value equal to one-half the detection limit. All concentrations are facility-averaged: i.e., multiple measurements from a single site are averaged, and the resulting population of facility averages used to generate the statistics in this table.

n/a = data not available

Sources: EPRI, 1991, 1992, 1994a, 1994b, 1996a, 1996b, 1997c, 1997d, 1997e, 1997f, 1997g, 1997h, 1997i, 1997j, 1997k, and 1997l

Table 3-9 includes the eight RCRA-regulated metals plus other constituents of comanaged wastes. Of these, the eight RCRA-regulated metals plus antimony, beryllium, boron, cobalt, copper, manganese, nickel, thallium, vanadium, and zinc are considered further in Section 3.4 for their potential risk to human health and the environment.

3.2.3 Wastes from Coburning Coal and Other Fuels

EPRI provided a summary of characterization data for wastes from the combustion of a variety of fuels and fuel mixtures that are sometimes coburned with coal (EPRI, 1997m). The data included both TCLP and total concentration analyses and comprised a small number of samples of wastes derived from each variety of different fuel mixtures. EPA compared the EPRI data to the data for UCCWs collected for the 1993 Regulatory Determination. Because of the small number of samples available for most individual fuel mixtures, EPA pooled the data reflecting samples of mixtures with similar components and similar characteristics into categories for comparison. Table 3-10 shows the specific fuel mixtures included in each category.

Table 3-10. Fuel Mixtures with Waste Characterization Data Available for Comparison to UCCWs

Category	Specific Mixtures Included in Category	
	Total Concentration Data	TCLP Data
Wood and Biomass	wood, biosludge/wood, railroad ties	wood
Mixed Plastics	mixed plastics/coal, mixed plastics/coal/lime	mixed plastics/coal, mixed plastics/coal/lime
Peat Mixtures	peat, peat/coal, peat/RDF, peat/coal/RDF, peat/coal/RDF/lime, peat/coal/packaging material, peat/coal/mixed plastics/lime	peat, peat/RDF
Oil Combustion Wastes	oil ash/coal (limited number of constituents)	none
Refuse Derived Fuel (RDF) Mixtures	RDF/lime, RDF/wood chips	RDF/wood chips
Manufactured Gas Plant (MGP) Wastes	MGP holder material/coal, MGP contaminated soil/coal	MGP holder material/coal, MGP-contaminated soil/coal, spent oxide box wastes/coal
Petroleum Coke Mixtures	petroleum coke/coal, petroleum coke/coal/MGP contaminated soil	petroleum coke/coal
Tire Derived Fuel (TDF) Mixtures	TDF/coal (limited number of constituents)	TDF/coal

Comparing total concentration data, EPA found that some types of fuel mixtures resulted in wastes with potentially higher levels of metals than UCCWs. Comparing TCLP data, EPA found that results were similar or below those for UCCW, with a few exceptions. Based on these comparisons, the available data indicate that, while leachate levels generally appear similar, coburning certain fuel mixtures may result in higher concentrations of some metals in the whole waste. This observation, however, is based on a limited number of samples for the wastes for coburning. The available data are not sufficient to draw statistically significant conclusions. The available data also do not indicate the percentages of each fuel component associated with the various mixtures sampled. Finally, data are not available on the chemical composition of the individual components of each mixture. Therefore, it is not possible to determine the source of elevated metals concentrations (i.e., it is not possible to say with certainty if the elevated concentrations result from the coal or the other fuels in the mixtures).

In addition to providing data on the inorganic constituents discussed above, EPRI's report on coburning (EPRI, 1997m) discusses organic constituents in combustion wastes from the various fuel mixtures. According to EPRI, most leachate and total composition analyses were below detection levels for organics. Fuel mixtures with some detected values included petroleum coke, mixed plastics, peat mixtures, RDF mixtures, MGP waste mixtures, and TDF mixtures. Detected organics included benzene, cyanide, dioxins, furans, PCBs, chlorobenzene, chlorophenol, and polycyclic aromatic hydrocarbons. Complete data on organics, however, are not presented in the report.

3.3 CURRENT MANAGEMENT PRACTICES

EPA used three sources of data to characterize UCCW comanagement practices:

- The 1994 EEI Power Statistics Database (EEI, 1994)
- The 1993 DOE study (DOE, 1993)
- The 1997 EPRI comanagement survey (EPRI, 1997a).

The EEI and DOE data cover the entire utility population. Because the majority of utilities comanage large-volume and low-volume wastes, data from these sources are believed to be representative of comanaging utilities as well. The EPRI comanagement survey specifically collected information on comanagement practices. The survey was voluntary and did not cover the entire utility population. However, the EPRI survey sample encompasses the majority of large-volume UCCW disposed in terms of volume (two thirds of the total generated in 1995). Based on comparison with data from the other sources, the EPRI sample appears representative of the population of UCCW management units in terms of the types of units included.

3.3.1 Unit Types and Location

Waste management units common at utility coal combustion facilities include landfills and surface impoundments. Box 3-3 defines these units. UCCWs at a facility may be managed together in the same waste management unit, or different UCCWs may be disposed in separate units. For example, fly ash may be sluiced to one surface impoundment, while bottom ash is managed in another. Also, different waste management units may service separate combustion units at an individual facility. Finally, as described above, UCCWs initially may be managed in a surface impoundment (or series of impoundments) and then dredged for placement in a landfill. As a result of these practices, a given combustion facility may have more than one waste management unit. The 1993 DOE study found 618 management units at 450 U.S. coal-fired power plants. The EEI Power Statistics database reports 561 units serving 440 facilities. Responses to the EPRI comanagement survey cover 323 UCCW management units serving 238 power plants.[2]

[2] The EPRI comanagement survey was voluntary and, thus, a complete population count was not expected. This explains the smaller number of power plants covered by the survey.

Box 3-3. Types of Waste Management Units

Surface impoundments are natural depressions, excavated ponds, or diked basins that typically contain a mixture of liquids and solids. UCCWs managed in surface impoundments typically are sluiced with water from the point of generation to the impoundment. The solid UCCWs gradually settle out of this slurry, accumulating at the bottom of the impoundment. This process leaves a standing layer of relatively clear water at the surface, which is commonly termed "head." The distance between the surface of the head and the top edge of the impoundment is known as "freeboard" and indicates the remaining capacity of the impoundment. The amount of freeboard in an impoundment may fluctuate as wastes are added, rainfall accumulates, and liquids are removed for discharge to surface water or recirculated to sluicing operations. Solids that accumulate at the bottom of a surface impoundment may be left in place as a method of disposal. The impoundment also may be periodically dewatered and the solids removed for disposal in another unit, such as a landfill.

Landfills are facilities in which wastes are placed for disposal on land. Landfills usually are constructed in sections called "cells." Wastes are placed in the active cell and compacted until the predetermined cell area is filled. Completed cells are sometimes covered with soil or other material, and then the next cell is opened. Cells may be constructed on top of a layer of previously completed cells, called a "lift." Landfills are usually natural depressions or excavations that are gradually filled with waste, although construction of lifts may continue to a level well above the natural grade. UCCWs managed in landfills may be transported dry from the point of generation, or they may be placed after dredging from a surface impoundment. Some residual liquids may be placed along with the dredged solids. Also, liquids may be added during the construction of the landfill for dust control purposes.

Source: EPA, 1988

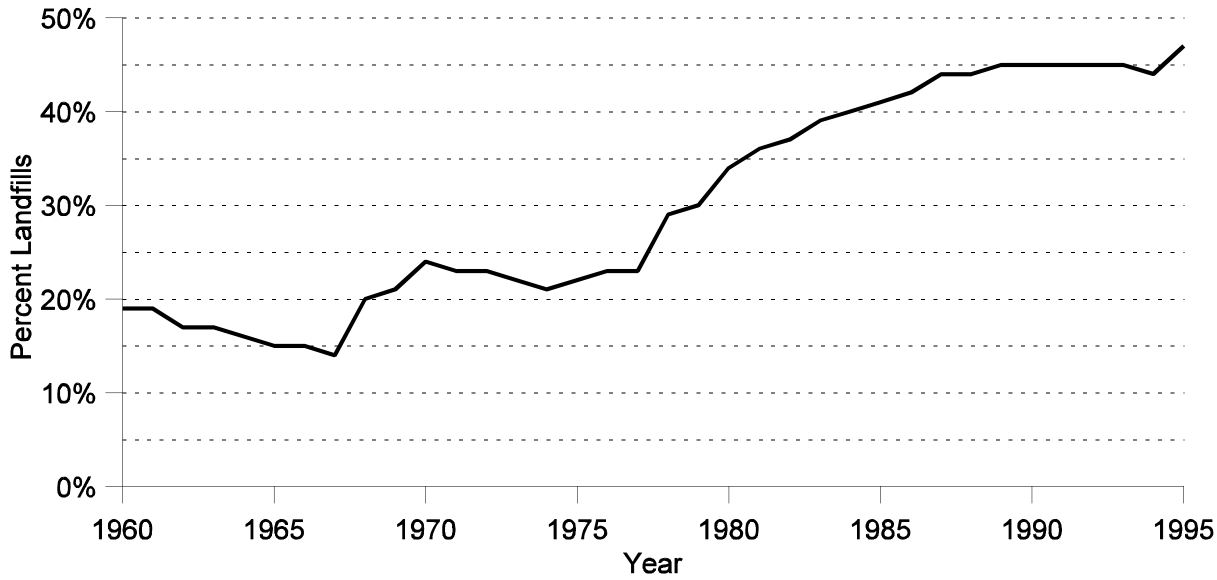
The three data sources show nearly equal numbers of surface impoundments and landfills. While slightly more than half of the units in the DOE study and EEI database are surface impoundments, just under half of the EPRI survey units are surface impoundments.

The population of units that comanage large-volume and low-volume wastes differ little from those of the UCCW management unit population as a whole. Slightly more than half (54 percent) of the 206 comanagement units in the EPRI survey are surface impoundments. This proportion is similar to the proportion of impoundments in the EPRI survey population as a whole. Furthermore, it is similar to the proportion of impoundments found in the other sources describing the population of UCCW management units.

Although each source shows a similar proportion of unit types, there appears to be a general trend toward the increasing use of landfills. Figure 3-4 shows that the proportion of landfills among new units has increased over time, based on the opening dates of the units in the EPRI comanagement survey. Units opened since 1970 are more likely to be landfills than surface impoundments.

Three factors may contribute to the trend toward the increasing use of landfills. First, space constraints at existing utility facilities favor the use of landfilling when new units are required. As discussed below, because of their greater height and material compaction, landfills can provide greater UCCW management capacity in smaller areas than surface impoundments. Furthermore, when space constraints are extreme, utilities must locate new UCCW management units offsite. When located offsite, landfills may be the preferred unit type because of the lower cost of transporting dry UCCW as opposed to wet UCCW. Second, New Source Performance Standards (NSPS) under the Clean Water Act require zero discharge of fly ash handling water (see Section 3.5.2). These requirements encourage the use of dry ash handling systems and, therefore, landfilling for new generating units. Third, there is an

Figure 3-4. Trend in Utility Coal Combustion Waste (UCCW) Management Unit Type



Source: EPRI, 1997a

increasing trend toward dry ash handling in general due to a steady increase in beneficial use applications (see Section 3.6.2), which favor dry ash collection and management.

Figure 3-5 identifies the geographic distribution of UCCW management units in the EEI Power Statistics database. The map shows the greatest number of units in the upper Midwest and fewer units in the far west and New England. This is consistent with geographic distribution of coal-fired utilities. Of more significance, Figure 3-5 indicates that surface impoundments outnumber landfills in the Southeast and some Midwestern states, while landfills outnumber surface impoundments in Texas and the Southwest.

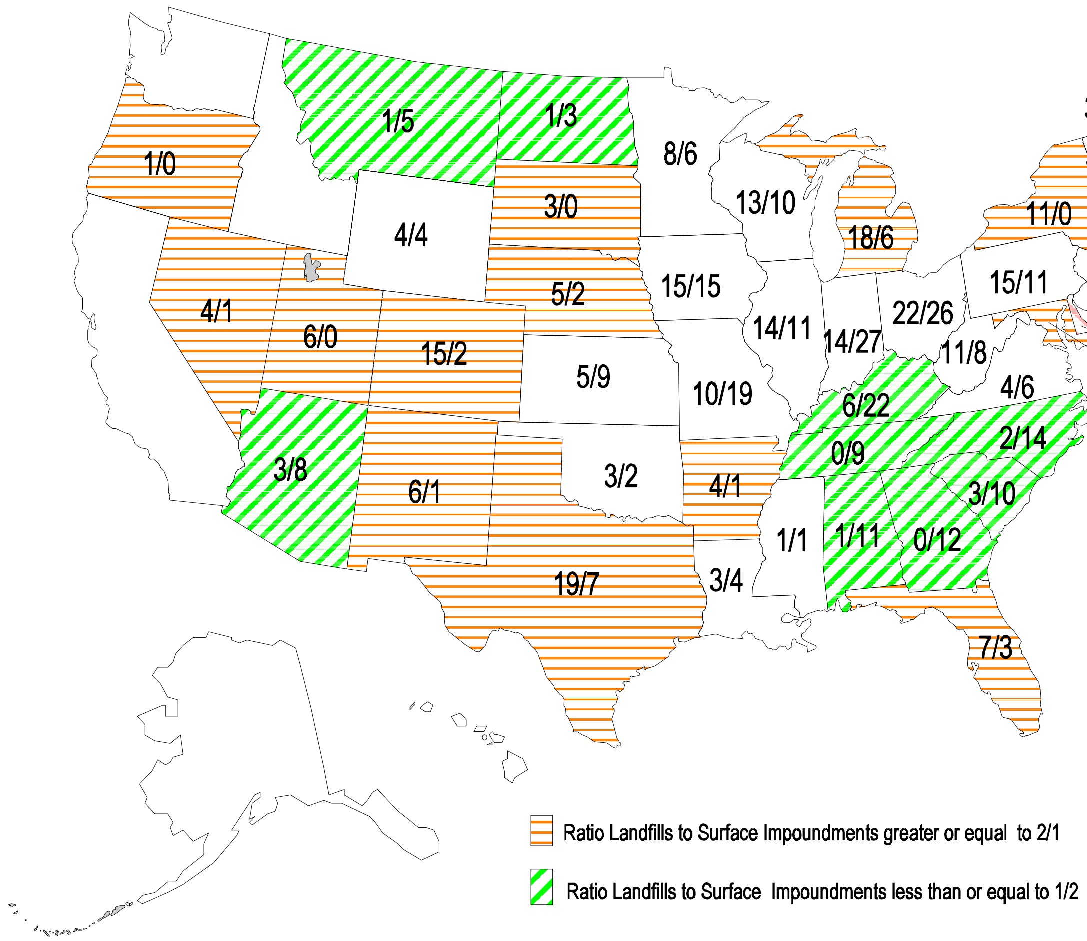
Based on data from the DOE study and EEI, the majority of UCCW management units are located at the generating site. Surface impoundments are almost exclusively found at the generating site (94 to 95 percent), while approximately half of landfills (49 to 59 percent) are onsite units. The extensive use of onsite management units likely is due to the large volume of waste generated. Offsite transportation costs can make onsite disposal more economical.

Power plants with the smallest generating capacity are more likely to use offsite units for UCCW disposal than are the largest power plants. As discussed above, the majority of offsite units are landfills. Thus, smaller generating facilities tend to favor offsite landfilling. Table 3-11 shows the trend toward offsite disposal for smaller facilities, probably due to space constraints and lower transportation costs for the smaller volumes of waste generated.

3.3.2 Types of Waste Managed

Individual waste management units at utilities may contain one or more of the large-volume UCCWs. Nearly 70 percent of the waste management units responding to the EPRI comanagement survey combine two or more large-volume UCCWs. The most common scenario is the combined

Figure 3-5. Geographic Distribution of Utility Coal Combustion Waste (UCCW) Management Units



Note: Numbers shown are number of landfills/number of surface impoundments.
Source: EEI, 1994

management of fly ash and bottom ash in a single unit, which is practiced in nearly half of the waste management units.

In addition to combining large-volume UCCWs, comanagement with low-volume wastes is a common practice at utilities. Comanagement, in fact, is practiced at the majority of utilities. Of the 253 active UCCW management landfills and surface impoundments in the EPRI survey, 206 (or 81 percent) comanaged large-volume wastes with at least one low-volume waste. These 206 comanagement units accounted for nearly 53 million tons (84 percent) of the 63 million tons per year of large-volume UCCW reported by all active units in the survey.

Both landfills and surface impoundments can comanage large-volume UCCWs and low-volume wastes. Solid low-volume wastes may be disposed directly in UCCW landfills or sluiced to UCCW surface impoundments. Liquid low-volume wastes may be sent to UCCW surface impoundments, either directly, following mixture with other low-volume liquids, or following some form of treatment. Solids settled from liquid low-volume wastes may be dredged and placed in UCCW landfills. Liquid low-volume wastes also may be managed in landfills when they are used for dust suppression and ash

Table 3-11. Unit Type by Power Generating Capacity for Utility Coal Combustion Waste (UCCW) Management

Generating Capacity	Number of Plants	Onsite Units		Offsite Units	
		Number	Percent	Number	Percent
0–100 MW	65	48	64%	27	36%
101–300 MW	83	65	72%	25	28%
301–600 MW	93	79	72%	31	28%
601–900 MW	60	64	77%	19	23%
901–1,450 MW	65	73	84%	14	16%
> 1,450 MW	74	101	87%	15	13%
Total	**440**	**430**	**77%**	**131**	**23%**

Source: EEI, 1994

conditioning. In addition to these direct forms of comanagement, liquid low-volume wastes may be comanaged indirectly, for example, by using them as sluice water for ash or as makeup water in wet FGD systems. These latter practices represent comanagement, as the low-volume wastes end up in the same management unit as the large-volume UCCWs.

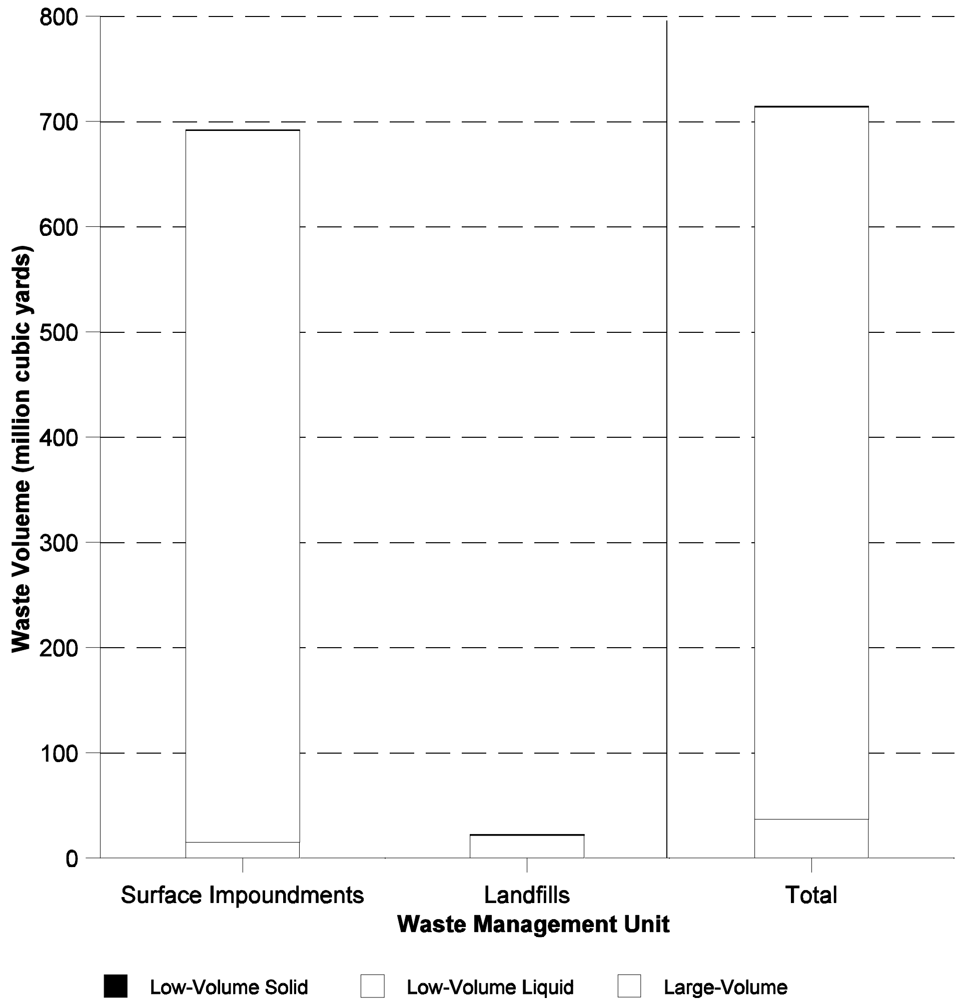
The EPRI comanagement survey collected data on the comanagement of all of the low-volume wastes described in Section 3.1 with UCCWs. It also collected data on commingling of UCCWs with other, more generic waste streams, such as municipal wastes, asbestos, and contaminated soils.

Low-volume wastes can, in fact, be comanaged in very large volumes. This is particularly true for liquid wastes, some of which can be generated at an individual facility at rates of millions of gallons per day. Based on EPRI comanagement survey data, *solid* low-volume wastes are managed in similar quantities in both surface impoundments and landfills. Much larger quantities of *liquid* low-volume wastes are managed in surface impoundments than in landfills. Figure 3-6 compares the volumes of large-volume and low-volume waste managed in the units responding to the EPRI comanagement survey.

Based on Figure 3-6, the volume of low-volume waste is nearly 20 times the volume of large-volume waste managed. The majority of this waste is low-volume liquid waste managed in surface impoundments. This seems plausible given the relatively large amounts of liquid used for sluicing ash to impoundments. A large quantity of low-volume liquid wastes was reported to be disposed of by a few landfills. This appears to be due to reporting errors in the survey responses. The estimate shown in Figure 3-6 assumes the median percentage of low-volume liquids reported by landfills is more representative of the population. Based on this estimate, the total quantity of low-volume waste (solid and liquid) disposed of in landfills is expected to be less than the quantity of large-volume waste disposed in these units.

Table 3-12 compares low-volume and large-volume waste quantities on an individual management unit basis. This table shows that the quantity of comanaged low-volume waste can range from an insignificant amount compared with large-volume UCCW, to a volume many times larger. In surface impoundments, the quantity of low-volume waste typically is many times that of large-volume waste, primarily due to the large quantity of liquids managed in these units. In landfills, the median value shows that the quantity of low-volume waste is a fraction of that of large-volume waste in many units.

Figure 3-6. Comanagement Volumes in Units Responding to EPRI Survey*



* 94 surface impoundments and 57 landfills provided waste quantity data. Assumes 1.3% solids content of liquid wastes.
Note: A large quantity of low-volume liquids was reported by a few landfills. This is believed to be the result of survey reporting errors. The estimate shown assumes the median value for the period of landfilled waste that is low-volume liquid.
Source: EPRI, 1997a

Individual surface impoundments and landfills may comanage as many as 15 different low-volume waste streams. Surface impoundments typically comanage more different waste types (a median of eight) than do landfills (a median of four). Also, the wastes most frequently comanaged differ for each type of management unit. Table 3-13 shows the frequency with which comanagement units receive each type of low-volume waste.

As noted above, facilities may indirectly comanage liquid low-volume wastes by using them as sluice water for high-volume UCCWs or as makeup water in wet FGD systems. The EPRI comanagement survey requested information on these practices. Of the 139 respondents that provided information about UCCW sluice water, 85 do not use low-volume wastes (i.e., they use only lake or river water or use recirculated pond water, which may not contain low-volume waste). Fifty-four respondents

Table 3-12. Low-Volume and Large-Volume Waste Compared by Management Unit

	Low-Volume Waste/Large-Volume UCCW	
	Landfills	**Surface Impoundments**
Number of Units	57	94
Minimum	0%	0%
Maximum	–[a]	248,650%
Median	3.9%	3,361%
Mean	4,214%[b]	12,646%

[a] The maximum value reported for a landfill is believed to be the result of a survey reporting error and is not presented here.
[b] The mean value calculated for a landfill incorporates a number of values believed to be reporting errors and, thus, is not considered representative of most landfills.
Note: Percentages shown are a comparison of low-volume waste with large-volume waste on an individual management unit basis.
Source: EPRI, 1997a

Table 3-13. Low-Volume Wastes Most Commonly Comanaged*

Waste	Percent of Landfills (95 units)	Percent of Surface Impoundments (111 units)
Coal Pile Runoff	39%	67%
Coal Mill Rejects/Pyrites	64%	70%
Boiler Blowdown	31%	67%
Cooling Tower Blowdown	23%	26%
Water Treatment Wastes	39%	58%
Regeneration Waste Streams	34%	74%
Air Heater or Precipitator Washes	38%	68%
Boiler Chemical Cleaning Wastes	32%	54%
Waste from Floor Drains and Sumps	39%	79%
Other Site Runoff	33%	60%
Miscellaneous Plant Wastes	25%	39%

* Frequencies shown include direct comanagement and indirect comanagement through use as sluice water or FGD makeup water.
Source: EPRI, 1997a

(or 39 percent) use at least one low-volume waste as sluice water. These respondents may use as many as 10 different low-volume wastes as sluice water, although the median is one low-volume waste. Of the 47 respondents that provided information about FGD makeup water, 14 do not use low-volume wastes (i.e., they use only lake or river water or use recirculated pond water). Thirty-three respondents (or 70 percent) use at least one low-volume waste as FGD makeup. These respondents may use as many as 10 different low-volume wastes as FGD makeup, although the median is two low-volume wastes.

3.3.3 Unit Size

Table 3-14 presents summary statistics on the capacities and dimensions of UCCW management units included in the EPRI survey. As shown in the table, landfills as a group have larger capacities than surface impoundments. This is because surface impoundment capacities are limited by their excavated depth or the height of their berms, whereas landfill lifts can continue to be constructed above grade, providing greater ultimate disposal capacity. The units in the EPRI comanagement survey have greater average capacities than units in the EEI database. This result may be because the EEI database includes more small generators than the EPRI comanagement survey.

Table 3-14. Management Unit Size for UCCW

	Landfills (110 units)			Surface Impoundments (107 units)		
	Capacity (cubic yards)	Area (acres)	Height (feet)	Capacity (cubic yards)	Area (acres)	Depth (feet)
Minimum	2,700	2.6	0.36	115,000	5	1
Maximum	82,000,000	900	150[a]	63,000,000	1,500	200[b]
Median	3,850,000	66	31	3,400,000	90	20
Mean	7,434,852	116	43	6,507,405	149	36

[a] One landfill yielded an estimated height of 356 feet and was omitted from this table. The data did not influence the calculated median value.
[b] One surface impoundment yielded 697 feet and was omitted from this table. The data did not influence the calculated median value.
Source: EPRI, 1997a. Height and depth data are derived from the reported capacity and area for each unit.

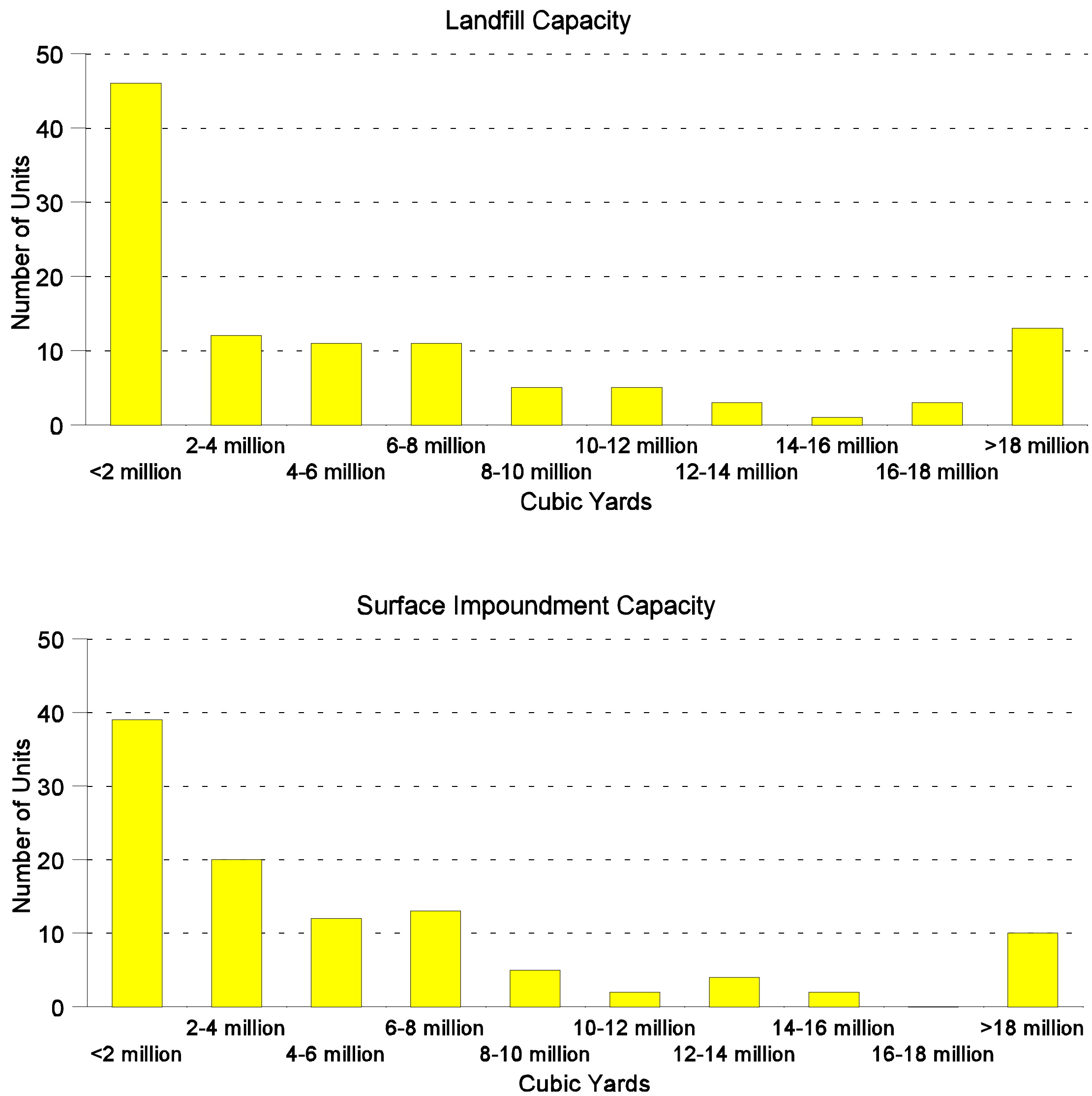
As shown in Table 3-14, the range of sizes for each type of UCCW management unit is great. Comparing the mean and median values for each unit type suggests that units are not distributed evenly throughout this range. Figure 3-7 graphically presents the size distribution of UCCW landfills and impoundments. Approximately 60 percent of units are less than 4 million cubic yards in capacity. Another 20 percent fall between 4 million and 8 million cubic yards. The remaining units are distributed over a broad range.

3.3.4 Environmental Controls

The EPRI comanagement survey collected information on the use of environmental control technologies, including liners, covers, leachate collection systems, and ground-water monitoring systems, at comanagement units. Box 3-4 provides a general description of each of these technologies. The EPRI comanagement survey also collected information on the types of regulatory permits and ground-water standards applied to comanagement units. While not control technologies in themselves, permits and standards are techniques used to ensure environmental control of waste management practices. For example, permits can dictate the use of specific operating practices and control technologies. Table 3-15 summarizes the use of environmental controls in UCCW comanagement units. The paragraphs below provide additional details and discussion of each type of environmental control.

An examination of the geographic distribution of new, lined surface impoundments suggests that liner requirements in several states have changed. The change from unlined to lined surface impoundments appears concentrated in the states of Georgia, Illinois, Indiana, Kentucky, Missouri, and Texas. These states account for 44 percent of the active comanagement surface impoundments in the EPRI survey. In these six states, only six (or 15 percent) of the impoundments opened before 1982 are lined. On the other hand, all of the impoundments opened since 1982 are lined. Data are available on

Figure 3-7. Size Distribution of Management Units for UCCW



Source: EPRI, 1997a

impoundment requirements in five of these six states (Georgia, Illinois, Indiana, Kentucky, and Texas) (CIBO, 1997c and EPA's review of requirement in Indiana). According to these data, these five states currently determine liner requirements for surface impoundments on a case-by-case basis. Therefore, if the trend in liner usage is driven by regulatory agencies in these states, it appears to result from a change in permitting policies rather than written regulations.

Liners

Table 3-15 presents liner data from the EPRI comanagement survey. The DOE study and the EEI Power Statistics database are in close agreement on the percentages of surface impoundments and landfills with a liner present. All three sources show that landfills are more frequently lined than surface

Box 3-4. Environmental Control Technologies

Liners. A liner is a barrier placed underneath a landfill or on the bottom and/or sides of a surface impoundment. Depending on their construction, liners can slow or prevent the release of leachate from a landfill or liquids from a surface impoundment to underlying soils and ground water. Liners can consist of compacted soil, compacted clay, a synthetic material or membrane, or a combination of barrier types.

Covers. A cover, or cap, is a barrier placed over the top of a waste management unit. Covers can prevent precipitation runoff from becoming contaminated by contact with waste, prevent or slow percolation of precipitation into the unit, and prevent windblown transport of waste. Like liners, covers can consist of compacted clay, synthetic materials or membranes, or a combination of materials. Covers also may be a layer of soil or sand. Final covers are those placed upon closure of a unit. Intermediate covers also may be placed on closed or inactive portions of a unit, particularly completed cells of a landfill. Daily covers are sometimes placed at landfills at the end of a day's operation.

Leachate Collection Systems. A leachate collection system is a series of drains placed beneath a unit, typically a landfill. These systems collect leachate for treatment or disposal, thus preventing it from reaching soils, ground water, or surface water.

Ground-Water Monitoring Systems. Ground-water monitoring systems consist of one or several wells drilled in the vicinity of a unit. Samples from these wells are periodically collected and analyzed. Ground-water monitoring is not strictly an environment control but rather a warning system. Ground-water samples that display contamination may trigger regulatory requirements to mitigate or eliminate the source of contamination.

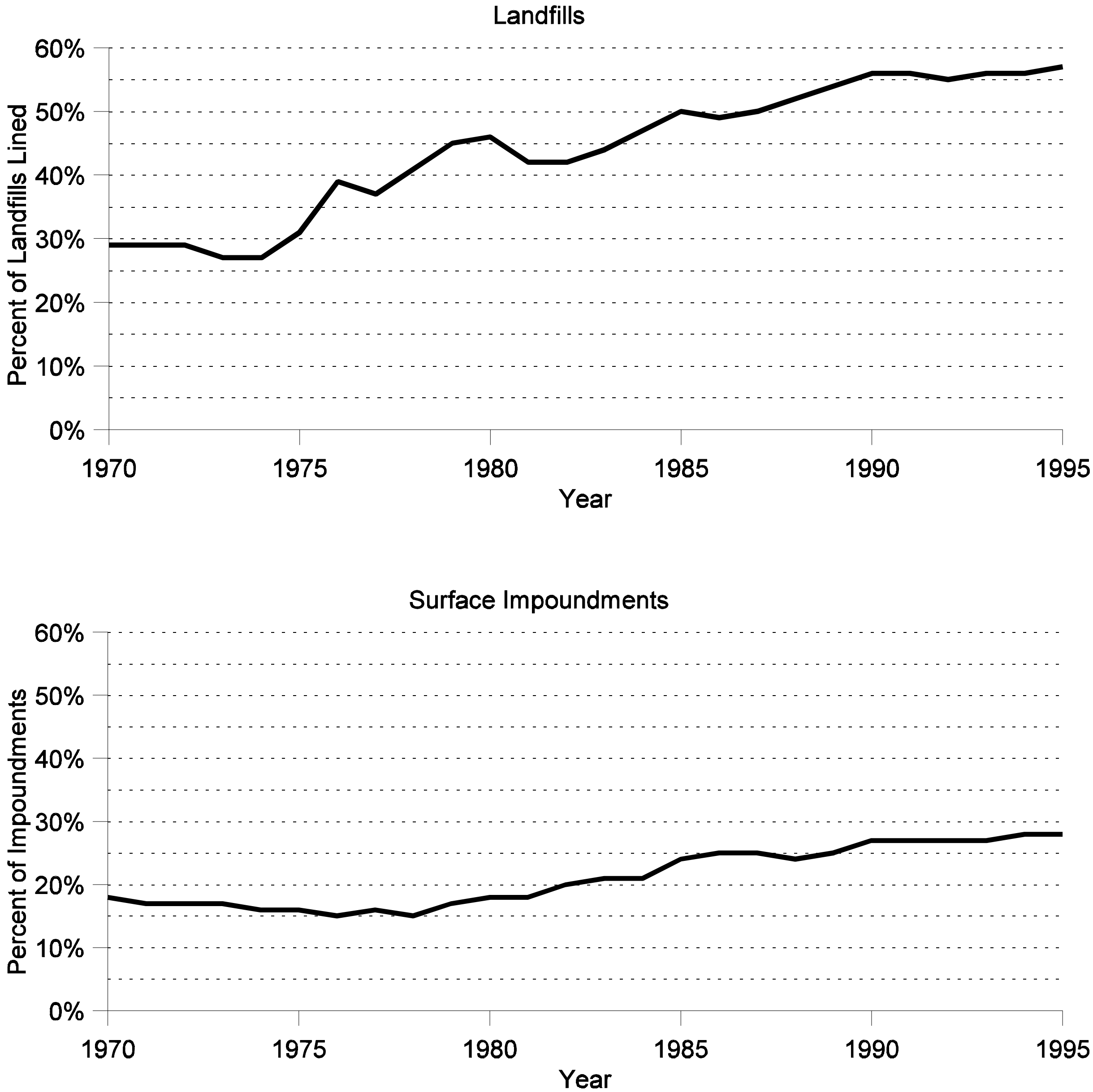
Table 3-15. Environmental Controls at UCCW Comanagement Units

Environmental Control	Landfills		Surface Impoundments	
	Number Reporting Data	Percent with Control	Number Reporting Data	Percent with Control
Liner	94	57%	111	26%
Cover	72	94%	47	30%
Leachate Collection	95	43%	111	1%
Ground-Water Monitoring	95	85%	111	38%
Ground-Water Performance Standards	94	77%	107	48%
Regulatory Permits	94	94%	110	85%
Source: EPRI, 1997a				

impoundments. This difference may be the result of two factors. First, state solid waste management regulations are more likely to mandate liners for landfills. As discussed in Section 3.5, many states do not impose specific design requirements (such as liners) on surface impoundments. When requirements are imposed, they typically are determined on a case-by-case basis. Second, as discussed above, newer units are more likely to be landfills than surface impoundments. These newer units would also be more likely to incorporate the latest environmental controls and regulatory requirements, such as liners.

For both landfills and surface impoundments, there is an increasing trend in the use of liners in newer units, as shown in Figure 3-8. This trend is consistent with the fact that liners are a modern development in the design of waste management units. This trend also may be the result of changing state regulations or permitting policies. As discussed in Section 3.5, new regulations or policies requiring liner usage typically affect only new units and do not apply retroactively to existing units.

Figure 3-8. Trend in Liner Utilization in Comanagement Units



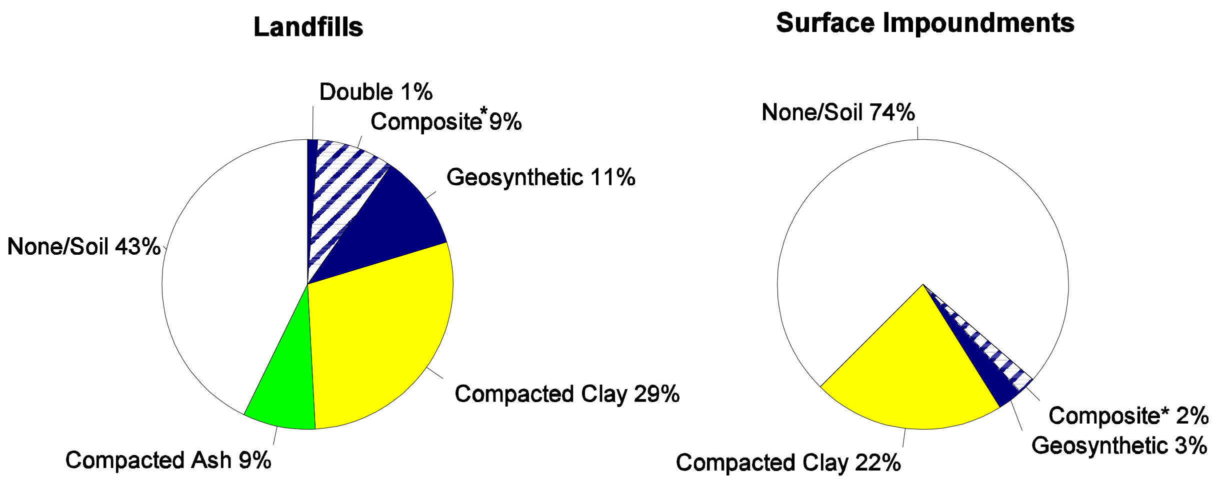
Source: EPRI, 1997a

Figure 3-9 displays the types of liners incorporated in the design of comanagement units responding to the EPRI survey. The most common liner material for both types of unit is compacted clay. Compacted clay typically has lower permeability than natural soils and, thus, serves as a better barrier between leachate and ground water. Several units reported using geotextile or composite liners. Several landfills reported using compacted ash as a liner.

Covers

As shown in Table 3-15, 94 percent of landfills and 30 percent of surface impoundments utilize some type of cover. Figure 3-10 details the types of covers used at these comanagement units. The data for currently active units probably are not indicative of the types of final covers that will be used when

Figure 3-9. Liner Types for Comanagement Units



*Composite liners include clay and synthetic layers.
Note: Percentages may sum to greater than 100 percent due to rounding.
Source: EPRI, 1997a

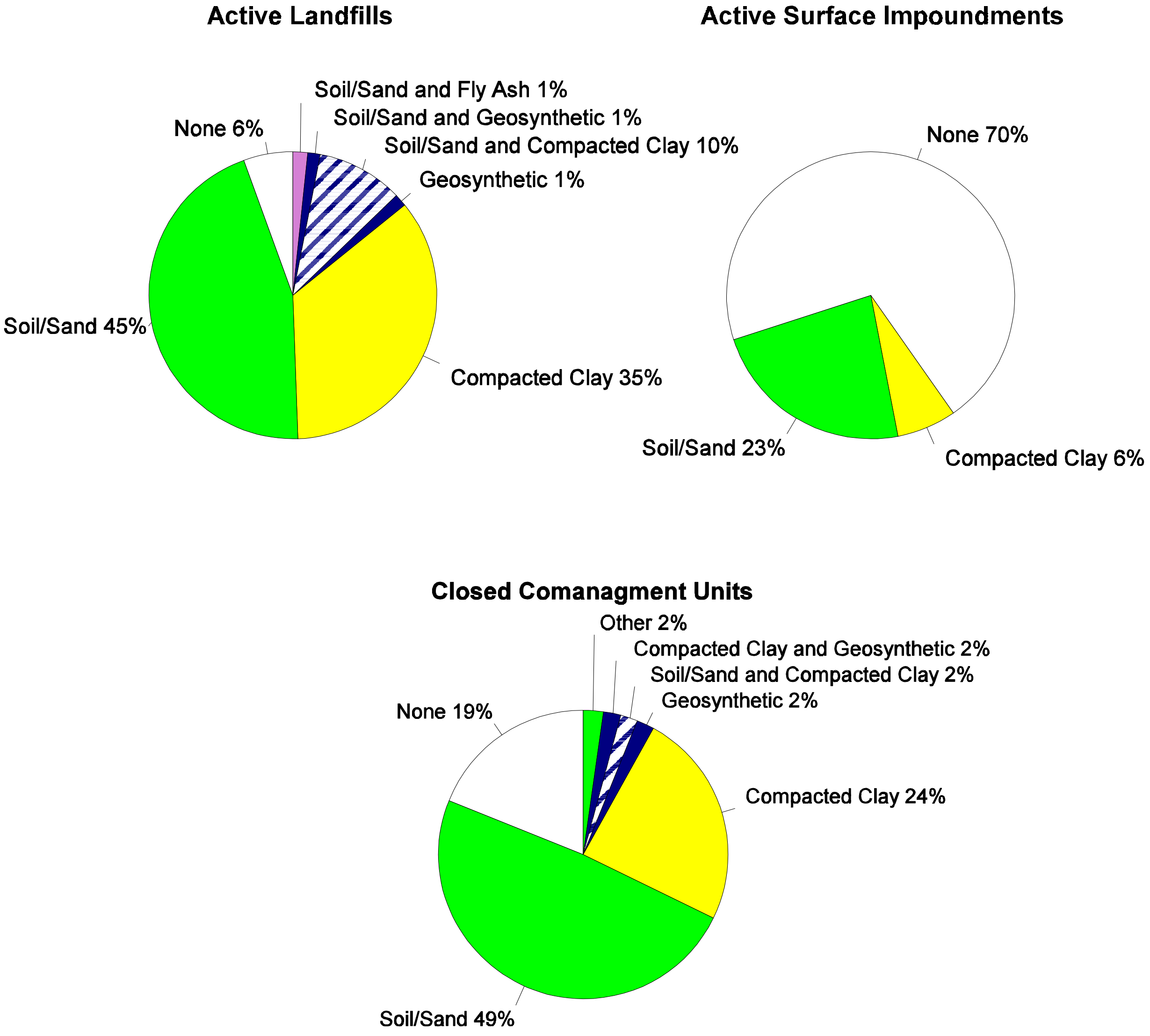
the units are closed. The results for landfills likely reflect interim cover on completed cells or daily cover used in active cells. Active landfills most commonly use sand, soil, or compacted clay for these purposes. Some active surface impoundments also use covers, usually soil or sand. The results for surface impoundments probably reflect cover placed on closed or full sections of active impoundments. Interpreting the percentages shown for impoundments is difficult. It is unclear whether the 70 percent of facilities answering "none" have closed, uncovered sections, or if their answer was intended to indicate that they have no closed sections.

Examining cover types used on currently closed units can provide a better sense of the types of final cover that will be applied to currently active comanagement units at the end of their useful life. Because of the design of the survey, the closed units were not required to indicate whether they comanaged low-volume waste. Three of the 57 closed units, however, did respond that they comanaged. All three of these are surface impoundments, two of which have compacted clay covers. The remaining surface impoundment did not provide cover information. An examination of all closed units provides a larger sample of cover information. Given the prevalence of comanagement, it is likely that many of these units comanaged low-volume waste at some time. Figure 3-10 shows cover types for closed units included in the EPRI survey. The survey responses, other than for the three surface impoundments discussed above, did not indicate whether closed units were surface impoundments or landfills. Of the 53 closed units that provided cover information, 81 percent used some type of cover. The most common type is soil or sand, although almost a quarter used compacted clay.

Leachate Collection

As shown in Table 3-15, 43 percent of the comanagement landfills in the EPRI survey include a leachate collection system. Very few surface impoundments (1 percent) have leachate collection. This difference may result from the difficulty of incorporating leachate collection systems into an impoundment design. It may also be the result of state solid waste management regulations dictating collection systems for landfills but not surface impoundments. As discussed in Section 3.5, many states

Figure 3-10. Comanagement Unit Cover Types



Note: Percentages for active landfills and active surface impoundments do not sum to 100 percent due to rounding.
Source: EPRI, 1997a

do not impose specific design requirements (such as leachate collection systems) on surface impoundments. When requirements are imposed, they typically are determined on a case-by-case basis.

Because a leachate collection system, like a liner, is an environmental control that is usually part of the initial design and construction of a unit, increasing use of these systems in newer units might be expected. Examination of the EPRI data, however, shows no such trend. Leachate collection appears to have been a part of comanagement unit design since the early 1960s, with new units no more likely than their predecessors to incorporate this control.

Ground-Water Monitoring

As shown in Table 3-15, 85 percent of landfills have some form of ground-water monitoring, compared with 38 percent of surface impoundments. This difference may be the result of state solid waste management regulations dictating ground-water monitoring for landfills but not surface impoundments. As discussed in Section 3.5, many states do not impose specific requirements on surface impoundments.

When requirements are imposed, they typically are determined on a case-by-case basis. Figure 3-11 shows an increasing trend in the use of ground-water monitoring at newer comanagement units. The trend appears particularly noticeable for surface impoundments. Although ground-water monitoring can be implemented at any point in the life of a waste management unit, it may be more likely in newer units because of more recent changes in state regulations or permitting policies. The operating permits for newer units may reflect new state ground-water monitoring requirements, whereas those for older units may not.

Ground-Water Performance Standards

As shown in Table 3-15, ground-water performance standards apply to 77 percent of comanagement landfills but only 48 percent of surface impoundments. The types of standards applied include numerical water quality standards, such as federal maximum contaminant limits (MCLs), and nondegradation standards under which current conditions are compared with past measurements. Some units, particularly landfills, have standards tailored for the particular site. The EPRI survey did not identify the consequences if ground-water standards were exceeded. Thirty-one of the units subject to ground-water performance standards (25 of them surface impoundments) do not have to monitor ground water. Therefore, it is unlikely that exceedences would be detected at these facilities.

Regulatory Permits

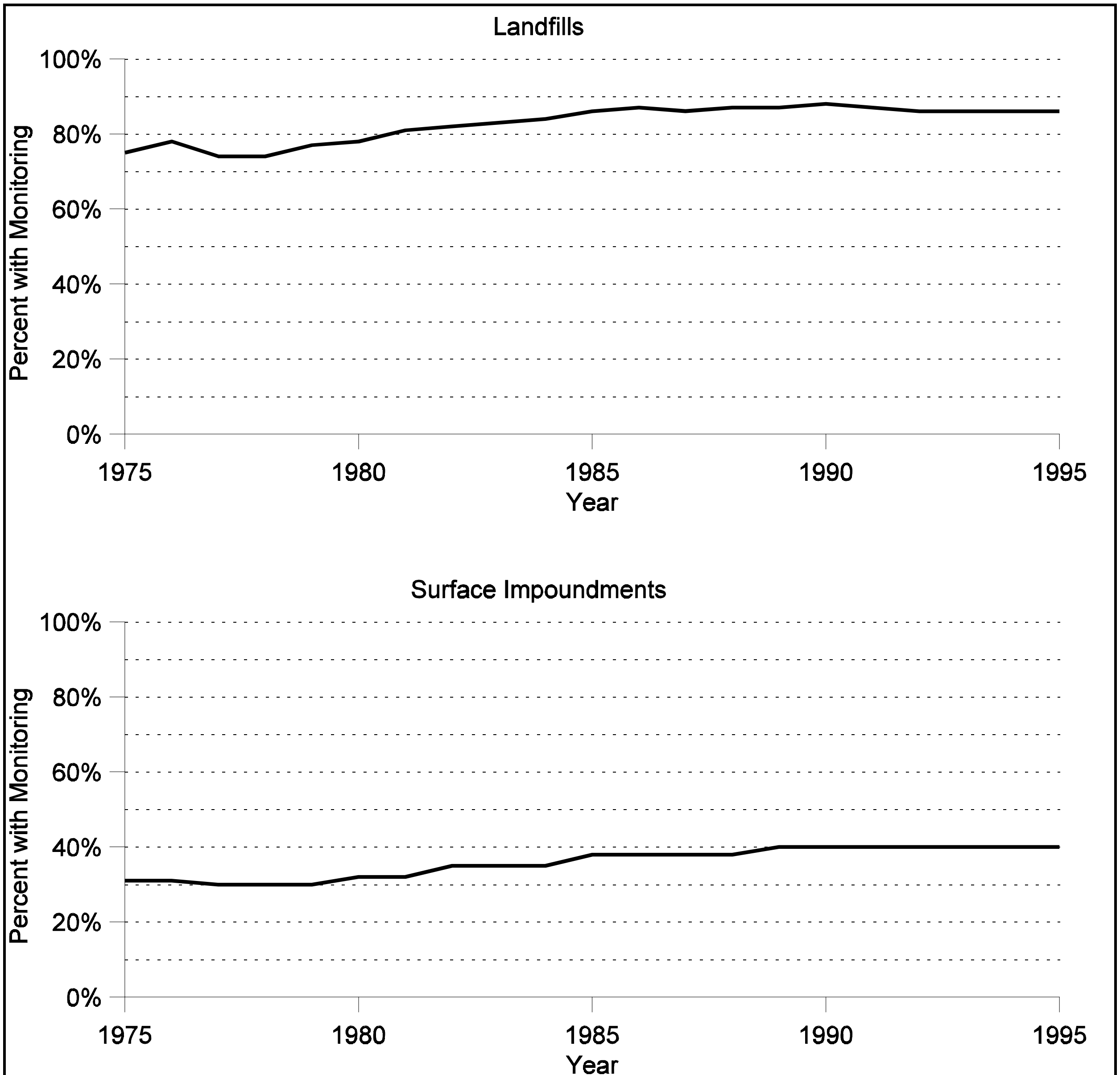
The EPRI comanagement survey collected information on whether units were covered by a regulatory permit and on the nature of the permitting agency (i.e., state, federal, or local). As shown in Table 3-15, the majority of comanagement facilities operate under a permit. Landfills are slightly more likely to face permitting requirements than are surface impoundments. In most cases, the permitting agency is a state government. Fourteen units (seven each of landfills and surface impoundments) are subject to the requirements of more than one permitting authority. Information on the degree of environmental protection required by these permits was not collected in the EPRI survey.

3.3.5 Beneficial Uses

In addition to traditional waste management in landfills and surface impoundments, UCCWs can be used in a variety of applications. Table 3-16 shows that substantial quantities of UCCWs currently are diverted from traditional management into beneficial use. An examination of historical data indicates that beneficial use of UCCWs has increased steadily over the past three decades (ACAA, 1996b; ACAA, 1998). Given the prevalence of comanagement, EPA believes that the quantities of UCCW used in some of these applications include comanaged wastes.

Categories of beneficial use include cement and concrete products, construction fills (including structural fill, flowable fill, and road base), agricultural uses, waste management applications, mining applications, and incorporation into other products. These beneficial uses are in varying stages of development. Some, such as minefilling and use in cement, have received widespread acceptance. Others are at the stage of pilot testing or bench-scale examination.

Figure 3-11. Trend in Comanagement Unit Ground-Water Monitoring



Source: EPRI, 1997a

The paragraphs below discuss the extent to which comanaged wastes may be amenable for these beneficial uses. Box 3-5 describes some of the major uses that may be potential management alternatives for comanaged wastes.

The extent to which comanaged wastes are amenable to beneficial use depends upon the specific use being considered. Some of the most developed uses, particularly in cement and waste stabilization, have met with success because of the pozzolanic or cementitious properties of some UCCWs (meaning that these wastes react with lime and water or water alone to form a hard matrix). Other uses, such as structural fill, snow and ice control, and blasting grit, take advantage of the physical properties (size and shape) of UCCWs. Agricultural uses have received some attention because of UCCW chemical properties (lime content and the presence of trace metal nutrients). The differences between comanaged

Table 3-16. Beneficial Use of Utility Coal Combustion Wastes in 1997

Beneficial Use	Volume in Tons					Percent of Generation
	Fly Ash	Bottom Ash	Boiler Slag	FGD Waste	All Wastes	
Cement and Concrete Products	9,421,903	604,705	10,755	202,423	10,239,786	9.7%
Structural Fill	2,877,535	1,384,327	84,669	91	4,346,622	4.1%
Waste Stabilization/Solidification	3,117,947	206,368	0	15,428	3,339,743	3.2%
Road Base/Subbase	1,417,600	1,286,585	792	17,797	2,722,774	2.6%
Blasting Grit/Roofing Granules	0	159,749	2,288,581	0	2,448,330	2.3%
Mining Applications	1,413,567	162,638	0	104,690	1,680,895	1.6%
Wallboard	0	0	0	1,603,762	1,603,762	1.5%
Snow and Ice Control	0	723,615	56,057	0	779,672	0.7%
Mineral Filler	285,580	130,888	108,796	0	525,264	0.5%
Flowable Fill	386,158	15,260	0	0	401,418	0.4%
Agriculture	34,571	8,197	0	55,644	98,412	0.1%
Other	362,501	414,572	29,200	183,527	989,800	0.9%
Total Use	**19,317,362**	**5,096,905**	**2,578,851**	**2,183,360**	**29,176,482**	**26.8%**
Total Generation	**60,264,791**	**16,904,663**	**2,741,614**	**25,163,394**	**105,074,462**	**100.0%**
Percent of Generation Used	31.5%	27.7%	92.9%	7.9%	26.8%	

Note: Individual values may not sum to totals due to rounding.
Source: ACAA, 1998

UCCWs and UCCWs managed alone may be of less concern when the comanaged wastes are used in applications solely to enhance the physical characteristics of a material (i.e., flowability, compressibility, and unit weight). However, changes in the chemical composition of UCCWs when comanaged may affect their advantageous pozzolanic or cementitious properties, particularly in applications benefitting from the incorporation of fly ash. Also, the management of UCCWs prior to their use can affect the types of uses for which they are amenable. According to the American Coal Ash Association's (ACAA) statistics, when UCCWs are managed in a surface impoundment prior to use, they are much less likely to be used for cement or concrete products and much more likely to be used in structural fills, mining applications, or as blasting grit (ACAA, 1998).

Comanagement may have a particular impact on cement and concrete applications. As shown in Table 3-16, the major application of fly ash, and that of UCCWs taken together, is in the production of cement and concrete products. When used alone, fly ash imparts added flowability to fresh concrete due to its spherical shape and fineness. Additionally, the pozzolanic properties of fly ash increase the comprehensive strength and the durability of the final concrete product. Excessive amounts of unburned carbon, high moisture, and low amounts of silicon, aluminum, and iron oxides in fly ash when improperly managed or when comanaged can increase its variability and interfere with the chemical reactions, ultimately degrading the quality of the cement or concrete product. This is of particular concern in structural grade concrete. Therefore, the American Society for Testing and Materials (ASTM) has

Box 3-5. Potential Beneficial Uses for Comanaged Wastes

Construction Fills. Construction fills include structural fills, flowable fills, and road base and subbase applications. Most of the bottom ash and a considerable portion of the fly ash utilized are applied in construction fills. This application of UCCWs ranks second following the use of UCCWs in concrete and cement products. In structural fills (e.g., backfills, embankments, area fills), fly ash and bottom ash replace natural materials and provide additional benefits not obtained with conventional fill materials, such as low compressibility, light unit weight, high shear strength, and pozzolanic properties. Unlike structural fills, flowable fills, such as backfills and grouts, are placed in slurried form and, therefore, benefit from the added flowability and strength development imparted by UCCWs. In road bases and subbases, the addition of UCCWs allows for greater long-term strength development.

Waste Stabilization/Solidification. Because of their alkalinity and presence of solids, UCCWs are used to chemically fix potentially hazardous wastes in a solid matrix. Through stabilization, hazardous organic and inorganic constituents are immobilized and prevented from being released to the environment. Stabilization may occur with or without solidification. Solidification consists, primarily, of converting soils, liquids, and sludges into a solid, structurally sound material prior to disposal or further utilization of the material. Waste stabilization and solidification represent the third largest beneficial use of UCCWs.

Blasting Grit/Roofing Granules. More than 2 million tons of UCCW**,** including almost all of the boiler slag and some bottom ash generated in 1997, were used as blasting grit and roofing granules. Like sand, boiler slag particles are used in sand-blasting operations and as roofing granules.

Mining Applications. Mining applications of UCCWs include controlling acid mining drainage, backfilling, blending mine soils and spoils, and revegetation. UCCWs are used in remediation activities at coal mines primarily because of their ability to neutralize the effects of acid drainage from mines and associated wastes. Mine subsidence problems from abandoned underground mines also are remediated by the use of these wastes as backfills. In addition, UCCWs are applied at the surface to promote vegetative growth and serve as a soil cover to prevent water infiltration to mine wastes.

Snow and Ice Control. Bottom ash and boiler slag are used as a substitute of salt for road de-icing operations. Approximately 780 thousand tons were used in 1997.

Mineral Fillers. Mineral fillers include a variety of fine particles that are incorporated into a broad range of industrial products. UCCWs have been used or evaluated for use as substitutes for commercial fillers in asphalt products, plastics, metal alloys, and fertilizers. The uses receiving the most attention are fly ash and boiler slag in asphalt and plastics. Fly ash also has been proposed as a mineral filler in carpet backing, vinyl flooring, joining and caulking compounds, industrial coatings and paints, and insecticides and pesticides. FGD sludges may have some potential as mineral fillers but have received little detailed scientific or engineering evaluation. Finally, because natural gypsum filler products have attained some commercial acceptance, FGD gypsum also has been considered for use as a filler, particularly in coated paper and joining compounds.

Agriculture. Fly ash, bottom ash, and FGD sludge are used for agricultural soil amendment. In general, these wastes can benefit agricultural systems by changing physical and chemical characteristics of soils, thus improving crop yield. UCCWs affect the chemical properties of soils by supplying essential plant nutrients for crop production and by modifying the soil to create a more favorable medium for plant growth. Physical changes brought about by UCCW amendments include reduced bulk density and increased aeration and water filtration. The potential benefits of using UCCWs in agriculture include alleviating soil trace elemental deficiencies, modifying soil pH, and increasing levels of needed calcium (Ca) and sulfur (S), infiltration rates, depth of rooting, and drought tolerance.

Sources: ACAA, 1996b; ACAA, 1998; EPA, 1998h developed standard specifications for fly ash used as a mineral admixture in Portland cement concrete. Guided by these requirements, generators may use specialized fly ash management practices when use in concrete is intended. These practices include segregating fly ash, as well as processing or cleaning the waste, prior to its use. In many cases, these standards and preprocessing operations may preclude the use of comanaged fly ash.

Another beneficial application considered waste-specific and, consequently, not suitable for comanaged waste utilization is wallboard production. Because of its similarities to natural gypsum, gypsum produced from FGD sludge is used as a substitute for the former in the manufacture of wallboard. The strength per unit weight provided by FGD gypsum greatly depends on its purity. Impurities such as fly ash, as well as lime and limestone found in FGD gypsum, could adversely affect the quality of the raw material and the final wallboard product.

The potential for beneficial use of comanaged wastes may be greatest in lower technology applications with less stringent specifications and where large volumes of material are needed. The feasibility of any specific use, of course, should be based on a detailed evaluation of the specific waste and its potential impacts in application.

3.4 POTENTIAL AND DOCUMENTED DANGERS TO HUMAN HEALTH AND THE ENVIRONMENT

Because of data limitations, EPA could not evaluate the site-specific potential for and historic occurrence of damages throughout the universe of existing coal-fired utility comanaged waste sites. Instead, EPA developed a methodology for estimating the potential risks associated with comanaged wastes relying on limited site-specific and industry-wide data, together with appropriate nationwide modeling techniques. Site-specific and regional data provided for this analysis to EPA were combined with nationwide environmental modeling data available to EPA from other modeling studies and from EPA's nationwide modeling database. EPA developed waste management scenarios representative of industry practices and environmental settings. To provide confidence in its model results, EPA conducted sensitivity analyses focusing on the driving model variables, and particularly on parameters for which only limited data were available. EPA also examined a wide range of state agency and EPA information sources to determine the past occurrence of damages at comanaged waste sites.

Previous work by EPA concluded that the greatest potential for harm from FFC wastes was associated with the potential for ground-water contamination (EPA, 1988; EPA, 1993b). Current EPA risk assessment policy also requires consideration of comprehensive human health risk (ground water and non-ground water) and ecological impacts. Accordingly, this FFC waste risk assessment included two components: the ground-water pathway human health risk assessment and the above-ground multi-pathway human health and ecological risk assessment. Section 3.4.1 presents the technical approach to and results of the ground-water pathway human health risk assessment for comanaged wastes. Section 3.4.2 presents the results of the above-ground multi-pathway risk assessment, which was conducted in close coordination with the ground-water study. Section 3.4.3 discusses potential and documented damage cases.

3.4.1 Potential Ground-Water Risks to Human Health

This section summarizes EPA's approach to and findings of its ground-water risk assessment efforts. Results of this study were originally presented in the *Technical Background Document for the Supplemental Report to Congress on Remaining Fossil Fuel Combustion Wastes, Revised Draft Final* (EPA, 1998d). EPA received peer reviewer and industry comment on the June 1998 study (*Peer Review* *of Fossil Fuel Combustion Risk Assessments: Original Comments from Peer Reviewers, July 1998*) and developed revised results in the October 1998 *Fossil Fuel Combustion Waste Risk Assessment: Revised Groundwater Analysis and Sensitivity Results* (EPA, 1998f). Original reports and comments are available in the docket supporting this report.

Overview of Approach

EPA followed a multistep assessment process including screening, deterministic modeling, and probabilistic modeling to determine the nationwide potential for risks to human health from ground-water contamination. EPA considered three individual receptors: an adult resident, a young child resident (age 1–10), and a child resident (age 1–19). For each receptor, EPA developed separate risk estimates for two waste scenarios: surface impoundments and landfills. See Chapter 2 of the *Technical Background Document for the Supplemental Report to Congress on Remaining Fossil Fuel Combustion Wastes, Revised Draft Final* (June 1998), available in the docket, for further discussion of the overall approach.

To identify the waste constituents of potential concern, EPA first performed a "screening-level" assessment. Screening involves comparing waste leachate concentrations with human health-based concentrations (toxicity levels) to identify and eliminate from consideration those leachate constituents too dilute to present risk even *before* transport in ground water to a receptor. The data provided to EPA indicated that no organic compounds of concern are present in the ash. EPA found that many metals of concern may be present in FFC waste leachates at concentrations greater than the corresponding health-based benchmarks. Therefore, EPA focused its screening efforts on the following: antimony, arsenic, barium, cadmium, chromium,[3] lead, mercury,[4] nickel, selenium, silver, thallium, vanadium, and zinc. For screening purposes, no dilution factor was assumed; leachate concentrations were compared directly with toxicity levels.[5]

EPA selected the *Composite Model for Leachate Migration with Transformation Products v1.2* (EPACMTP) to model the movement in ground water of metals of concern released from waste landfills and surface impoundments. Waste management scenarios were developed for use with EPACMTP using site-specific, industry-wide, and general nationwide information to estimate values for parameters describing waste and management unit properties (e.g., unit size, waste density), unit environmental settings (e.g., recharge rate, soil properties, ground-water velocity), and contaminant properties (e.g., retardation factors). Each scenario was used to predict the peak metals concentrations expected to occur in a nearby drinking water well during a 10,000-year study period. Comparing the predicted peak concentration with the health-based benchmarks, EPA estimated the risk to an individual receptor exposed through ingestion of the contaminated drinking water.

EPA calculated estimated risks for each scenario by selecting combinations of variables most likely to produce high-end (to include the 95th percentile of all possible risks) results. EPA then performed probabilistic modeling to determine where the deterministic results fell within a distribution of

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[3] Available chromium data for comanaged wastes were limited to total chromium, which were used as a conservative estimate of hexavalent chromium (CrVI) for screening purposes.

[4] Only two samples of comanaged waste leachate showed mercury concentrations above detection levels. Despite the low frequency of detection, mercury was carried forward in the analysis.

[5] This is in contrast with earlier FFC Waste (1993), Cement Kiln Dust, and Mineral Processing Waste studies, in which a dilution factor of 10 was assumed to reflect a 10:1 dilution of leachate in ground water.

estimated risks. Finally, EPA performed sensitivity analyses to improve its confidence in the overall estimate of risks. EPA varied individual variables and combinations of variables throughout wide ranges of values, finding that model results changed very little except in response to the most sensitive parameters (e.g., waste management unit size, waste concentration, receptor well location, contaminant retardation rate). As part of the sensitivity analysis, EPA compared EPACMTP model results with the output of an industry-sponsored model, MYGRT v 2.0, and found general agreement between the models with respect to predicted down-gradient concentration and time to reach risk when similar input values were used.

Calculation of Benchmarks

The starting point for the ground-water pathway risk assessment was the calculation of health-based benchmark concentrations ("health-based levels" [HBLs] sometimes referred to as health-based numbers or HBNs). Each HBL represents the concentration of a contaminant in drinking water to which a specified receptor is exposed above which adverse health effects may be expected to result. The value is calculated from a combination of toxicological information, ingestion rate, frequency and duration, and receptor body weight.

Screening Assessment Results

As discussed in Section 3.2, EPA developed a profile of comanaged waste characteristics using industry-provided data collected from comanaged waste landfills and impoundments. For impoundments, EPA relied upon *in situ* pore water samples taken from waste drill cores. For landfills, EPA used both laboratory leachate tests developed using the TCLP, and industry-provided water extract data from *in situ* solids samples collected from several landfills. EPA calculated the 95th percentile waste concentration for each metal of concern in comanaged wastes and compared it to the corresponding HBL.[6] The results of the screening exercise, shown in Table 3-17, determined those constituents that could be eliminated from further consideration, and those constituents warranting additional consideration.

In the table that follows, and for all subsequent risk discussions, screening and modeling results are expressed in terms of cancer risk or hazard quotients (HQ). Cancer risk, always expressed in powers of ten, refers to the incremental individual lifetime risk of developing cancer. For this study, arsenic is the only known carcinogen for which risks were calculated. For all other constituents of concern, results are expressed as HQ. An HQ equals the modeled concentration level divided by the HBL.

It is important to note that the screening approach employed did not rule out many metals of potential concern. In fact, the HQ for most metals was less than 10, such that employing a fixed ground-water dilution factor at this step would have eliminated many more metals from additional consideration. However, because preliminary modeling indicated that the predicted dilution factors might sometimes be less than 10, EPA elected to adopt the more conservative approach described here.

Modeling Scenarios Considered

EPA developed contaminant transport model scenarios to estimate the level of ground-water contamination that might result from the release of comanaged waste leachate from management units.

[6] Note that since the number of values available for each constituent was generally less than 20, the 95th percentile value generally was set equal to the maximum value observed.

Table 3-17. Constituents Remaining after Screening Analysis for Coal-Fired Utility Comanaged Wastes

Constituent	Observed 95th Percentile Concentration (mg/L)	Screening Result
Wastes Managed in Surface Impoundments		
Arsenic	9.64	Risk = 3.3×10^{-2}
Cadmium	0.156	HQ = 6.0
Chromium (as VI)	0.746	HQ = 5.0
Lead	0.468	31 times action level
Nickel	8.33	HQ = 8.1
Selenium	1.03	HQ = 4.0
Vanadium	0.8	HQ = 2.2
Zinc	23.1	HQ = 1.5
Wastes Managed in Landfills		
Arsenic	0.24	Risk = 8.3×10^{-4}
Barium	3.6	HQ = 1.0
Cadmium	0.044	HQ = 1.7
Selenium	0.44	HQ = 1.7
Thallium	0.015	HQ = 3.7

Notes: Constituents were evaluated at their high-end (95th percentile) concentration. Constituents that screen out are as follows: antimony, barium, copper, mercury, and silver for surface impoundments; antimony, chromium, copper, lead, mercury, nickel, silver, and zinc for landfills. Landfill data are calculated as presented in the October 10, 1998, Sensitivity Analysis.
Source: EPA, 1998d (Chapter 5)

Waste management scenarios were developed for use with EPACMTP using site-specific and industry-wide information to estimate values for parameters describing the following:

- Waste and management unit properties (e.g., unit size, saturated hydraulic conductivity)
- Unit environmental settings (e.g., weather, soil properties, ground-water velocity and volume)
- Contaminant properties (e.g., retardation factors).

EPA developed a central tendency scenario by setting all EPACMTP model parameter input values at or near the midpoint of the range of values for the industry. EPA also developed a high-end scenario by setting the two most significant parameters (waste concentration and receptor well location) at their respective high ends. In addition to the high-end deterministic scenario, EPA used the Monte Carlo capabilities of EPACMTP to perform a probabilistic assessment of risk for each waste management scenario. The Monte Carlo analysis resulted in a distribution of risk estimates from 2,000 model runs in which each of the model's input parameters was allowed to vary independently. In accordance with EPA's current policy, with respect to measuring occurrence of risk, high-end risks and Monte Carlo results are emphasized.

For comanaged utility wastes, EPA modeled landfills and surface impoundments. Risks from minefills were evaluated using other analytical techniques primarily, as discussed below, due to difficulties in modeling the movement of water through mining disturbed strata. (As noted in the discussion of minefills, it is possible to approximate surface mine transport using the landfill scenario, under certain conditions. The landfill scenario can not be used to approximate underground mine transport, however.) Risk from agricultural application of comanaged waste is discussed in the non-ground-water section below.

A complete listing of model input values is presented in the June 1998 *Technical Background Document for the Supplemental Report to Congress on Remaining Fossil Fuel Combustion Wastes, Revised Draft Final* (EPA, 1998d) and the October 1998 *Fossil Fuel Combustion Waste Risk Assessment: Revised Groundwater Analysis and Sensitivity Results* (EPA, 1998f). All the above may be found in the docket supporting this report.

Modeling Results

Table 3-18 summarizes selected results from the deterministic and probabilistic analyses of risk from comanaged wastes for the adult receptor. Overall, EPA found that the risks associated with all modeled constituents of concern, except for arsenic, fell below an HQ of 1 or a lifetime cancer risk of 1×10^{-6}. Potential risks associated with arsenic in both the landfill and the surface impoundment high-end deterministic scenarios exceeded 1×10^{-6}.

Comparison of the deterministic and Monte Carlo results reveals that the deterministic results always exceeded the 95th percentile Monte Carlo result. For example, none of the 2,000 Monte Carlo simulation combinations of parameter values performed for arsenic for the surface impoundment scenario yielded a risk estimate as high as the high-end deterministic result. Similarly, the high-end risk for arsenic, chromium, nickel, and selenium from the comanaged waste landfill exceeded 99 percent or more of the corresponding Monte Carlo simulation results. At the 95th percentile level, the arsenic risks predicted by the Monte Carlo simulations of the landfill and surface impoundment scenarios were roughly 1 order of magnitude or more below the corresponding risks estimated for the high-end scenarios.

Table 3-18. Comparison of Deterministic and Monte Carlo Risk Model Results for Comanaged Waste Ground-Water Pathway Scenarios

Scenario	Constituent[a]	Deterministic Risk, Central Tendency	Deterministic Risk, High-End	Corresponding Monte Carlo Percentile	Monte Carlo 95th Percentile
CS[b]	Arsenic	3×10^{-6}	5×10^{-4}	>100	1.6×10^{-5}
CL[b]	Arsenic	4×10^{-7}	3×10^{-4}	>99.9	4.3×10^{-5}
	Chromium	HQ <1	HQ = 0.2	>99.4	HQ = 0.1
	Nickel	HQ <1	HQ <0.1	>100	HQ = 0.01
	Selenium	HQ <1	HQ = 0.8	>100	HQ = 0.1

[a] All other metals modeled resulted in HQ <1
[b] CS = comanaged waste impoundment; CL = comanaged waste landfill
Note: Results shown are those from the October 10, 1998 Sensitivity Analysis

EPA also considered the time at which risks were predicted to result from the release of constituents of concern in each of the scenarios. EPA found that the concentration of arsenic in ground water at the receptor well would not reach the HBL for arsenic (e.g., achieve a risk level of 1×10^{-6}) for roughly 500 years.[7] For the landfill, the predicted time to reach a risk of 1×10^{-6} or more was found to exceed 3,500 years.[8]

Table 3-19 summarizes the estimated risks to adult and child receptors for the high-end deterministic scenarios for comanaged wastes. Overall, the results show that for noncarcinogens the risks for young children increased roughly twofold compared to the adult receptors. For arsenic, the risk for young children increased roughly 25 percent compared to the adult receptors.

Table 3-19. Comparison of Adult and Child Risk Model Results for Comanaged Waste Ground-Water Pathway Scenarios

Scenario	Constituent[a]	High End Deterministic Risk		
		Adult	Young Child	Child
CS[b]	Arsenic	5×10^{-4}	6.3×10^{-4}	4.4×10^{-4}
CL[b]	Arsenic	3×10^{-4}	3.8×10^{-4}	2.6×10^{-4}
	Chromium	HQ = 0.2	HQ = 0.35	HQ = 0.22
	Nickel	HQ = 0.1	HQ = 0.2	HQ = 0.1
	Selenium	HQ = 0.8	HQ = 1.4	HQ = 0.9

[a] All other modeled metals yielded HQ <1
[b] CS = comanaged waste impoundment; CL = comanaged waste landfill
Note: Results shown are from the October 10, 1998, Sensitivity Analysis.

3.4.2 Potential Above-Ground Multi-Pathway Risks to Human Health and the Environment

Human Health Risks

This section summarizes EPA's approach to and findings of its above-ground human health risk assessment efforts. Results of this study were originally presented in *Non-groundwater Pathways, Human Health and Ecological Risk Analysis for Fossil Fuel Combustion Phase 2* (EPA, 1998e). EPA received peer reviewer and industry comment on the June 1998 study (*Peer Review of Fossil Fuel Combustion Risk Assessments: Original Comments from Peer Reviewers, July 1998*) and subsequently developed revised results. Original reports and comments are available in the docket supporting this report.

Overview of Approach

As in the case for the ground-water risk assessment (Section 3.4.1), EPA conducted a broad above-ground risk assessment to estimate potential risks associated with direct and indirect exposure to wastes and waste contaminated media. EPA employed the Indirect Exposure Methodology (IEM) used in several previous Office of Solid Waste (OSW) risk assessments (e.g., Cement Kiln Dust, Hazardous

[7] See EPA, 1998d, page 5-33.

[8] Ibid. The value shown here is for the FBC landfill. Based on sensitivity analyses and the change from porewater to TCLP concentrations for landfill waste characterization, the time to reach peak will equal or exceed the value reported for the FBC landfill.

Waste Identification Rule). Using IEM, EPA estimated the concentration of constituents of concern in air, soils, and plant and animal tissues resulting from airborne and waterborne releases of comanaged wastes. EPA then estimated the human health risks associated with exposure to the contaminated media for a wide range of exposure scenarios. To provide confidence in its model results, EPA conducted sensitivity analyses for each scenario, constituent, and receptor, focusing in particular on those driving parameters for which only limited information was available.

IEM considers two major release mechanisms: wind erosion and surface water erosion and runoff. EPA concluded that these releases may occur in three comanaged waste scenarios: active landfills, dewatered surface impoundments without cover, and agricultural application projects where comanaged wastes are employed as soil amendment. Estimation of waste management unit sizes and waste characteristics for these scenarios was coordinated with the ground-water risk assessment for consistency. For each scenario, EPA considered the following transport pathway and exposure routes:

- Inhalation of contaminants transported through air emission and dispersion. Only concentrations of respirable PM 10 were considered for the inhalation exposure route.

- Ingestion of soil contaminated through deposition of air emissions and contaminated runoff. For the soil amendment scenario, soil was contaminated by intended application of the waste product.

- Ingestion of fruits and vegetables contaminated through direct deposition to the plant and deposition to soil with subsequent plant uptake. For root vegetables, contamination results from deposition to soil followed by root uptake.

- Ingestion of beef and dairy products contaminated through cows' ingestion of contaminated soil, grain, forage, and silage. These media are contaminated via the same mechanisms stated above.

- Ingestion of fish taken from an effected stream located near a waste management unit or agricultural field, and contaminated by runoff, erosion, or direct deposition.

For each release pathway and exposure route, EPA considered a variety of receptors. These included an adult and child resident near the waste management unit, a subsistence farmer and child of subsistence farmer for the agricultural application scenario, and a subsistence fisher.

For each receptor, EPA calculated risk based on toxicological information, receptor-specific exposure assumptions, and the predicted concentration of constituents of concern in the contaminated media. EPA calculated central tendancy risks by setting all IEM model parameter input values at or near the midpoint of the range of values for the industry. EPA also calculated high-end risks determining the pair of parameters that, when placed at their respective high-end values, yield the highest estimate of risk for the specific scenario.

Overview of Modeling Results

In essence, no risks from the ingestion exposure route were found in excess of 10^{-6} (cancer), or with HQs in excess of 1, except for arsenic in the case of agricultural applications and when managed in an onsite active landfill. For both the landfill and the impoundment, for arsenic, ingestion risks were found at the 10^{-6} level for both the farmer and the child of the farmer. In the agricultural use scenario, EPA found arsenic risks from this composite and complex pathway to be at five times the 10^{-5} level (a level consistent with the findings of EPA's ongoing cement kiln dust evaluation in which the arsenic waste concentrations were similar to, but slightly below on average, those of FFC total wastes). While some other risks at the "10^{-6} or hazard quotient of 1" margin were found, the very conservative nature of the analysis combined with the intrinsic cementitiousness of the ash (meaning it will harden and not blow, erode, or runoff as readily as otherwise—a consideration difficult to simulate) together lead EPA to conclude, with the same data sufficiency caveat as for ground water, that only the agricultural use non-ground-water pathway poses meaningful risk.

Table 3-20 summarizes the differences between adult and children's above-ground risk where the risk exceeded 10^{-6}.

Table 3-20. Comparison of Adult and Child Risk Model Results for Comanaged Waste Above-Ground Ingestion

Scenario	Constituent	High End Deterministic Risk	
		Adult*	Child
Utility Coal Landfill	Arsenic	2.5×10^{-6}	1.7×10^{-5}
Utility Coal Dewatered Impoundment	Arsenic	2.1×10^{-6}	2.0×10^{-6}
FBC Waste Landfill	Arsenic	1.0×10^{-6}	8.2×10^{-6}

* High-end deterministic risk from ingestion. The very slight differences for the landfills are not considered significant, primarily due to the cementitiousness of the ash.

Risks in the 10^{-6} range were found for inhalation exposure route for chromium. It should be noted that only total chromium was reported. For this assessment chromium was modeled as the more toxic chromium VI valence—a conservative assumption. This, coupled with other conservative assumptions (including the cementitiousness issue) leads EPA to believe that there are no plausible excess risks from the inhalation exposure route.

Ecological Risks

EPA has developed explicit guidelines to evaluate the ecological risks associated with chemical and non-chemical stressors (see EPA, 1998g). Consequently, EPA developed a technical approach that was consistent with the guidelines and addressed the management goal for the ecological risk analysis, succinctly stated as follows: "to evaluate the potential for adverse ecological effects associated with the management and/or use of comanaged FFC residuals anywhere within the contiguous United States."

The *Guidelines* (EPA, 1998g) describe the three basic phases that frame the ecological risk assessment process: problem formulation, analysis, and risk characterization. In brief, these phases may be summarized as follows:

- **Problem formulation phase.** During this phase, the problem statement is developed within the context of stated management goals and constraints on resources and timeframe. The endpoints for the analysis are selected, a conceptual model is developed, and an analysis plan is prepared for estimating exposure concentrations and risks. The conceptual model identifies ecological receptors potentially at risk and relevant exposure pathways. For rulemakings intended to be national in scope, assessment endpoints and measures of adverse effects are often chosen to be broadly applicable across the United States.

- **Analysis phase.** The analysis phase involves the use of simulation models to predict constituent concentrations in the environment to which ecological receptors are exposed (i.e., exposure profile). In addition, this phase describes how ecotoxicological data are used to develop appropriate measures of adverse effects to various ecological receptors (i.e., stressor-response profile). The simulation models are mathematical constructs that represent fate and transport processes from source releases into various environmental media where they may be taken up by plants and animals.

- **Risk characterization phase.** Characterizing ecological risks often involves the comparison of predicted exposure concentrations to chemical stressor concentration limits (CSCLs) for soil, sediment, and surface water intended to represent *de minimus* risks to wildlife. The comparison of predicted exposure concentrations to CSCLs is generally referred to as the HQ approach and provides a quantitative indication of the potential for adverse ecological effects. The HQ results are accompanied by a narrative explanation of the assumptions, limitations, and uncertainties inherent in the assessment. The relevance of the findings to the management goals and the ecological significance of potential effects (as indicated by the HQ values) also are discussed.

The ecological risk analysis was implemented using a tiered approach that proceeded from conservative onsite screening evaluations to increasingly detailed assessments of representative ecological receptors exposed to chemical releases simulated from comanagement facilities (e.g., surface impoundments, landfills). Chemical concentrations in comanagement facilities were identified from available data distributions and high-end (approximating the 95^{th} percentile) and central-tendency (approximating the 50^{th} percentile) concentrations were simulated. The same fate and transport models used to simulate chemical movement through the environment and resulting human exposures also were used to predict ecological exposures. In essence, the similarity in exposure pathways for human and ecological receptors allows similar fate and transport models to be used for both components of the analysis.[9] The exposure concentrations predicted for environmental media in generalized freshwater and terrestrial habitats were compared to the CSCLs for representative ecological receptors, including species of mammals, birds, and amphibians, as well as collections of soil, sediment, and surface water organisms. Because the intent of this analysis was to identify the *potential* for adverse ecological effects, conservative benchmarks for “no adverse response” were chosen whenever they were available. These benchmarks often are based on subchronic studies at low chemical concentrations for sensitive endpoints, such as developmental effects. For amphibians, however, the adverse effects benchmarks were based on relatively high levels of lethality (typically 50-percent lethality).

The risk estimates (i.e., HQ results) for landfills and land application units suggest that ecological risks associated with the release and surface transport of chemicals of concern are not likely to be significant for these management/use practices. Because these results are generally based on no effects levels for mammals and birds, it is expected that even threatened and endangered mammalian and avian species are unlikely to receive exposures that would warrant concern. It is difficult, however, to provide unequivocal support to that assertion without the benefit of a more site-based analytical framework. In addition, the subsurface pathway was not evaluated in this analysis, and there is some concern that this pathway may be significant in areas with high water tables that intersect critical wetlands and estuarine systems.

[9] Resource constraints, in combination with analytical difficulties associated with estuaries, did not permit specific estuarine analysis.

The risk estimates for comanaged coal ash surface impoundments and associated drainage systems indicate that this scenario is of special concern. Wildlife frequently utilize surface impoundments and nearby wetlands as part of their habitat and, in particular, the HQ ratios for amphibians indicate that the chemical concentrations in surface impoundments may be associated with high levels of lethality (i.e., the CSCLs for amphibians correspond to 50-percent lethality). Amphibian sensitivity to these trace metals has been demonstrated in case studies on FFC residuals, and selenium and aluminum are believed to be particularly toxic to amphibian species. In contrast, the risk estimates shown for mammals and birds may predict more subtle effects on reproductive capacity and the HQ ratios are based on no adverse response levels. In addition, the probability of wildlife being directly exposed to surface impoundment water will vary depending on the surrounding habitat and the location of the impoundment, so there is considerable uncertainty associated with these risk estimates. The most likely receptor to be exposed would be avian species that are able to circumvent barriers to forage or nest in pond areas. Transitory exposures to migratory birds are possible during seasonal migrations and longer-term exposures are possible depending upon the nesting behavior of a given species. Although this exposure scenario may affect relatively few species, the local effects on a particular species or habitat may be undesirable. Table 3-21 summarizes the HQ results for surface impoundments for high-end and central-tendency chemical concentrations.

Table 3-21. Summary of Ecological Risk Results for Comanaged Waste Impoundments[a]

Constituent	High-End HQ	Central Tendency HQ	Receptor Group
Aluminum	10	1	Amphibians
Arsenic	19	<1	Birds
Boron	16	<1	Amphibians
Selenium	29,622	153	Mammals
	5	<1	Amphibians

[a] For this pathway, standing water samples collected from surface impoundments were used to represent media concentrations. No fate and transport modeling was conducted.

3.4.3 Documented Damages to Human Health and the Environment

Summary of Findings

EPA identified a total of six sites at which comanagement of coal combustion wastes has occurred and which meet the “test of proof” for damage cases (see Section 1.4.3). Five of these sites were previously identified in the 1988 Report to Congress and the 1993 Regulatory Determination (58 FR 42473, 8/9/93). A sixth site was more recently identified by EPA. Detrimental effects from these sites included the presence of contaminants in drinking water wells above MCLs and vegetative damage in wetlands or streams.

EPA finds that most of the sites showing damages are older unlined units. In most cases, the units are closed and stopped receiving wastes in the 1980s and may not have used management practices similar to those used today. At the same time, the damage cases demonstrate the potential for comanaged wastes to present a danger to drinking water supplies or the environment.

Based on information available and consideration of EPA’s “tests of proof,” EPA identified the cases in Table 3-22 as potential damage cases.

Table 3-22. Damage Cases

Damage Case	Wastes Present	Event	Test of Proof	Comment
Coal-Fired Utility Comanaged Wastes				
Chisman Creek (VA) (88)	Petroleum coke and coal ash landfill	Vanadium, selenium, and sulfate in ground-water wells	Scientific/ Administrative	Other possible sources of contamination; 1 of 2 major cases cited in Report to Congress
Faulkner Offsite Disposal Facility (MD)	Coal ash and pyritic mill rejects	Landfill and collection pond seepage and discharges resulted in plant and fish impacts to adjacent wetlands; pH the major COC	Scientific/ Administrative	Remediation included pond liners, landfill cover, and sequest-ration of pyrites
DPC – Old E.J. Stoneman Ash Pond (WI)	Coal ash, demineralizer regenerant, other water treatment wastes	'Gross contamination' by pond cited by State – MCL exceedences of Cd, Cr, Zn, and sulfate; B near 5 mg/L in private well	Administrative	Closure plan required relocating town water supply well
Basin Electric W.J. Neal Station (ND)	Coal ash and sludge; comanaged wastes probable	Cr and other metals detected in downgradient sediments, ground water	Administrative (limited information available)	Site closed and capped and pending NFRAP (No Further Remedial Action Planned)
VEPCO – Possum Point (VA)	Coal ash, pyrites, oil ash, water treatment wastes, and boiler cleaning wastes	Ground water contaminated with Cd and Ni, attributed to pyrites and oil ash	Administrative	Response included sequestration of oil ash, pyrites, and metal cleaning wastes to separate lined units.

Damages from Comanaged Wastes Identified in the 1988 Report to Congress and 1993 Regulatory Determination

In the 1988 Report to Congress, EPA identified two sites that meet the "test of proof" criterion for damage cases. In preparing the 1993 Regulatory Determination, EPA identified four additional sites meeting the test of proof. EPA determined that four of these six damage cases were associated with comanagement. These findings were presented in the 1993 Regulatory Determination. With the exception of one site (i.e., Faulkner), EPA did not conduct further research or investigation of these sites beyond what was presented in the record for the 1993 Regulatory Determination. The four comanagement sites are discussed below.

- **Chisman Creek, Virginia** (described in the 1988 Report to Congress). Fly ash and bottom ash from the burning of coal and petroleum coke were managed in a disposal pit. The site was on the National Priority List as of 1988. Drinking water wells became green from vanadium and selenium contamination, and contained selenium above the primary MCL and sulfate above the secondary MCL.[10]

[10] Based on the limited data discussed in Section 3.2.3, waste from coburning coal and petroleum coke may be higher in vanadium on average than UCCWs. Therefore, ash from petroleum coke may be a more likely source of vanadium than ash from coal combustion.

- **Possum Point, Virginia** (described in the 1993 Supplemental Analysis). At this site, oil ash, pyrites, boiler chemical cleaning wastes, coal fly ash, and coal bottom ash were comanaged in an unlined pond, with solids dredged to a second pond. Levels of cadmium above 0.01 mg/L were recorded prior to 1986 (the primary MCL is 0.005 mg/L). After that time, remedial actions were undertaken to segregate wastes (oil ash and low volume wastes were believed to be the source of contamination). Following this action, cadmium concentrations were below 0.01 mg/L.

- **Faulkner, Maryland** (initially described in the 1993 Supplemental Analysis). Pyrites, fly ash, and bottom ash were comanaged in unlined landfills. In 1991, the state of Maryland found that water quality in a nearby stream and creek were degraded by landfill leachate, with effects including orange staining from iron precipitation and low pH (3 to 4). Vegetative damages also were observed. An underlying aquifer was found to be affected by the landfill leachate. The acidic leachate was believed to have resulted from pyrite oxidation. Remedial measures at the site included closure and capping of older units, installation of liners in newer units, and discontinuing mill reject comanagement at the facility.

- **Old E.J. Stoneman Ash Pond, Wisconsin** (described in the 1993 Supplemental Analysis). Ash, demineralizer regenerant, and sand filter backwash were managed in an unlined pond from the 1950s to 1987. Nearby private drinking water wells had elevated levels of sulfate and boron relative to background. Monitoring wells installed around the pond showed exceedences of the primary MCL for cadmium and chromium, but these constituents were not detected in the drinking water wells. As a result of the presence of indicator parameters in the drinking water wells, the state concluded that other parameters may reach the wells in the future and therefore required the operator to close the site and provide alternative drinking water to the affected residences.

Additional Damages Identified Since 1993

Since 1993, EPA has become aware of additional candidate damage cases involving comanaged wastes. EPA used information supplied by EPRI regarding 14 comanagement sites, as well as other case study reports, and conducted a search of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Information System. In a number of cases, EPA found that comanagement units have affected ground-water quality, a conclusion which is supported by EPRI's work. Only one of the cases reviewed by EPA, however, meets the Agency's "test of proof" to be considered a damage case for purposes of this investigation. This case, the Basin Electric Surface Impoundment (BESI) site, was identified through the CERCLA information system. Significant findings regarding this site are summarized below.

The BESI site at the WJ Neal Station in Velva, North Dakota, is an unlined, diked impoundment that received various construction debris and ash from the burning of sunflower seed hulls as well as fly ash and sludge from a nearby coal-fired power plant from the 1950s until the late 1980s. A site inspection report and power cooperative records from BESI confirmed that fly ash and sludge from BESI's coal-fired power plant were deposited in the impoundment. Monitoring efforts and negotiations for plant closure began in 1982 after chromium was found at 8.15 parts per million (ppm) in the sludge pond, in excess of the standard for chromium. A Preliminary Assessment in 1989 indicated migration of contaminants into the underlying aquifer that supplies Velva with drinking water, although sampling data were not provided. Areas of soil contamination within the impoundment were consolidated and the impoundment was capped when the site was closed in 1990. EPA has concluded the contamination was a result of activity that occurred before the cap was in place.

3.4.4 Compliance History of the Fossil Fuel Electric Power Industry

To further characterize the environmental impacts of the fossil fuel electric power generation sector, EPA examined the sector's compliance, enforcement, and legal history. The data utilized in this section were gathered from the 1997 *Fossil Fuel Electric Power Generation Sector Notebook* (EPA, 1997c), which obtained data from EPA's Integrated Data for Enforcement Analysis (IDEA) database system. Since the IDEA system accesses data through Standard Industrial Classification (SIC) codes, information in the *Sector Notebook* deals only with those facilities whose primary SIC codes indicate the potential for power generation activities.

A review of the compliance history of the industry in the 5 years from 1992 to 1997 indicates the following:

- Of the 3,270 facilities identified as power generators, approximately 66 percent (2,166) were inspected during the 5-year period.
- The 14,210 inspections conducted during the 5-year period lead to 403 facilities having 789 enforcement actions taken against them.
- The sector had an average enforcement-action-to-inspection ratio of 0.06 during this 5-year period.

A comparison with other sectors identified by the *Sector Notebook* project revealed the following:

- When compared to sectors with similar number of facilities, a much higher percentage of facilities in the power generation sector were inspected during this 5-year period. Moreover, the number of inspections during the 5 years for the fossil fuel electric power generation sector is more than three times the number conducted in most other sectors.
- The enforcement-action-to-inspection ratio of 0.06 during the 5-year period is one of the lower rates of the listed sectors.

In addition, a comparison of the data across sectors by environmental statute indicates that both inspections and enforcement actions at electric power facilities are driven by air regulations. The majority of electric power facility inspections (57 percent) and enforcement actions (59 percent) are under the Clean Air Act (CAA).

Lastly, the number of major environmental cases to affect the fossil fuel electric power industry is small. Even though there were 789 total enforcement actions between 1992 and 1997, there were few major cases involving fossil fuel electric power generation facilities. Since 1992, there have been at least 13 such actions. None of the cases were for violations of regulations directly related to the management of solid or hazardous wastes. The 13 cases were broken out as follows:

- Six cases under the CAA (emissions standards for asbestos, nitrogen oxide monitoring violations, and sulfer dioxide violations)

- Two cases under the Clean Water Act (CWA) (discharge permit violation, wetlands)

- Two cases under the Toxic Substances Control Act (TSCA) (polychlorinated biphenhyls, or PCBs)
- Two cases under the Emergency Planning and Community Right-to-Know Act (EPCRA) (release in excess of reportable quantities)
- One multimedia case (CWA, EPCRA, and TSCA).

The average penalty associated with these cases was more than $150,000.

The two most significant cases against fossil fuel electric power generation facilities included CWA violations by Potomac Electric Power Company (PEPCO) and CAA violations by Public Service Electric & Gas (PSE&G). In the PEPCO case, the violations occurred between 1988 and 1993, during which time a site supervisor either pumped or oversaw the pumping of polluted water from holding ponds into an adjacent swamp. PEPCO discovered the illegal discharge and informed EPA. The consent decree provides for a penalty of $975,000. Because the violation was self-disclosed, no criminal charges were brought against the company or its officers.

In *United States v. Public Service Electric & Gas*, PSE&G was charged with violating the CAA, specifically the National Emissions Standards for Hazardous Air Pollutants (NESHAP) for asbestos. An off-duty EPA inspector noticed a pile of old pipes in a yard. A subsequent inspection of the old gas-cracking operation revealed the NESHAP violations. PSE&G was required to pay a civil penalty of $230,000 and complete an extensive worker training and notification program.

3.4.5 Minefill Risks

EPA has found that operators may use or dispose of UCCWs in a variety of mining applications. Ash has been used for surface mine reclamation, mine subsidence control, mine water management, waste stabilization, and other applications. In addition, surface and underground mines have been used for locating ash and/or sludge landfills. While currently available statistics indicate that beneficial use in mine environments accounts for less than 2 percent of large volume wastes generated (ACAA, 1998), EPA believes that mine use and disposal of FFC wastes may increase.

EPA believes that, under ideal circumstances, placement of wastes in mines should present no increased risks to human health and the environment relative to conventional landfills. In fact, minefills could result in net environmental benefits relative to conventional landfills through avoided development of Greenfield space for UCCW disposal, improvement of disturbed mine lands through contouring, revegetation and reduced infiltration to mine workings, and abatement of acid mine drainage through neutralization and diversion. Both surface and underground minefills, however, may present existing or potentially emerging conditions that are quite distinct from ideal landfill conditions with respect to environmental risks. Some potential minefill conditions are introduced below.

- **Fractured flow.** Many surface mines are characterized by underlying fractured hydrogeologic formations that may permit channel flow of contaminated ground water. Moreover, underground mines may present channels for mine water movement that extend for miles. Fractured flow conditions present the possibility that contaminated ground water can move considerable distances to reach potential receptors.
- **Acid mine drainage.** Many coal mine environments, particularly in the eastern United States, are impacted by acid mine drainage (AMD), in which sulfide minerals associated

with the coal seam oxidize in the presence of air and water to produce sulfuric acid. The resulting acidic leachate can mobilize constituents of concern from surrounding host rock. Some mine reclamation projects rely on the available alkalinity of UCCWs to reduce the potential for generation of acid from sulfide minerals in mine spoils. In other cases, the hope is that alkaline UCCWs will neutralize mine waters already impacted by pyrite oxidation. If the available alkalinity in UCCWs is consumed by AMD, however, continued leaching may mobilize the constituents of the ash or sludge.

- **Intersection with ground water.** Many surface and underground mines are completed below the natural level of ground water surrounding the excavation. During active operations, mine water must be pumped from the mine pit or void to allow access to the resource. In such instances, mine water will flood the mine workings once active operations cease. Some mine placement projects rely on the self-cementing or augmented cementing properties of UCCWs to seal mine workings and limit mine water intrusion. Other projects have demonstrated that, once placed, UCCWs may harden to form mine water diversions. Placement of UCCWs in mines completed below the water table will result in inundation of the wastes. Inundation may result in continued leaching of constituents of concern from the wastes.

EPA intends to evaluate the risks associated with mine placement of FFC wastes. Gaps in currently available information and modeling complications prevented EPA from completing its evaluation of minefill risks for this report.

Case studies, when available, are preferable to modeling; however, EPA does not have detailed case studies that present sufficient information to evaluate the performance of minefill projects. Many of the sites for which the Agency does have information lack background characterization and well location information such that pre- and post-placement conditions cannot be compared and conditions below the fill cannot be related to the fill activities.

EPA currently lacks sufficient information to generalize about the background conditions at mine sites. The potential transport of constituents of concern depends in part on the geochemical conditions of receiving waters. Background pH plays an especially important role in precipitation/dissolution chemistry as leachate enters ground water. EPA has demonstrated the sensitivity of EPACMTP to changes in pH for some metals of concern; however, the Agency has insufficient information to characterize the background conditions in ground waters at surface and underground coal mines. Background characterization is especially important in minefill evaluation because many mine sites are characterized by very poor existing ground-water quality, including low pH.

Another important consideration is depth to ground water. The depth to ground water can play an important role in attenuating constituents of leachate released from waste management units. EPA is aware that some states restrict the placement of UCCWs in beneficial use projects from placement within some minimum distance above ground water. Most of the site-specific information that EPA has obtained to date, however, does not indicate the depth to ground water.

EPA also has insufficient information on the design of actual minefill projects. The Agency has reviewed limited technical information on a variety of minefill projects, but lacks sufficient information to generalize about the size, depth, and environmental controls (e.g., liners, covers, monitoring) characterizing minefill projects nationwide. EPA is aware that some operators amend existing mine spoils with UCCWs in conjunction with reclamation plans. EPA is unaware of typical mixing ratios in such projects. Similarly, the Agency needs information about typical resulting permeability ranges for combined ash and spoils or other fill materials.

Minefill scenarios present significant modeling challenges as well. First, EPACMTP does not accommodate fractured flow conditions. As a result, underground and some surface mine situations cannot be modeled using this tool. Further, EPA has not developed or identified a model suitable for predicting the emergence of acid generating conditions within UCCW minefills. Of equal importance, EPA has not identified a model suitable for predicting the consumption of alkalinity in UCCW materials by AMD intrusion into the fill.

3.5 EXISTING REGULATORY CONTROLS

EPA's objective in this section was to identify and evaluate the existing regulatory controls that pertain to the comanagement of UCCWs. The regulatory analysis is directed toward addressing the question of whether existing regulations are adequately protecting human health and the environment. The analysis also is helpful in understanding waste generation and current management practices.

The sections below discuss regulations addressing air pollution, water pollution, and solid and hazardous waste, respectively. Air regulations are relevant primarily because of their effect on waste generation. Water regulations have an influence both on waste generation and management and, in particular, address the impact of UCCWs on surface waters. Solid and hazardous waste regulations are of the greatest interest because they directly govern waste management practices.

The sections below describe federal regulations in each of these areas. In many cases, the implementation of these federal programs is carried out by the states; therefore, where appropriate, aspects of state implementation also are discussed. Because the nuances of state implementation are of particular importance with respect to solid waste regulation, that section discusses state programs in detail. Where appropriate, that section also describes state control on two beneficial uses of concern to EPA: minefilling and soil amendment.

3.5.1 Regulations Addressing Air Pollution

The CAA is intended to protect and enhance the quality of the nation's air resources. The most relevant of the CAA requirements include the following:

- National Ambient Air Quality Standards (NAAQS) for particulate matter (PM)
- NAAQS for sulfur dioxide
- Title IV acid rain provisions
- NAAQS for ozone
- National Emissions Standards for Hazardous Air Pollutants (NESHAP).

Historically, CAA requirements have been a significant factor affecting the generation and collection of certain large-volume UCCWs (specifically fly ash and FGD waste). Recent and forthcoming changes in these requirements also may impact waste generation or characteristics, as discussed below.

NAAQS for Particulate Matter

The NAAQS for PM establish maximum concentrations of PM with diameter less than or equal to 10 micrometers (PM10) in the ambient air. These standards are among the factors motivating the use of particulate control technologies at coal-fired utilities. EPA recently proposed to lower the size criterion to 2.5 micrometers, which may affect the volume of fly ash collected and selection of control technology; however, final standards will not be issued for at least 5 years, so the impact of the new size criterion is difficult to predict at this time.

The NAAQS for PM are implemented through New Source Performance Standards and State Implementation Plans.

New Source Performance Standards (NSPS). The NSPS subject newly constructed or modified units to specific PM emissions limits. These limits may be met by changing fuel types, modifying combustion conditions, or installing control devices. The applicability of the NSPS and the specific limits imposed vary with the age and size of the combustion unit, with older and smaller units less likely to be subject to the NSPS. Specifically, the regulation of facilities can be considered in the following four categories.

- 40 CFR 60 Subpart D governs the standards of performance for new fossil fuel-fired steam generators that were constructed or underwent major modification after August 17, 1971. Subpart D affects only units that are capable of burning fossil fuels at greater than 73 megawatts (MW) of heat input rate.

- Subpart Da affects utility units with the capacity to fire fuel at greater than 73 MW heat input rate that commenced production or major modification after September 18, 1978.

- Subpart Db affects coal-fired units with the capacity to fire fuel at greater than 29 MW of heat input rate that commenced construction or modification after June 19, 1984.

- Subpart Dc governs coal-fired units constructed or modified after June 9, 1989, with capacity to fire fuel at less than 29 MW but greater than 8.7 MW of heat input rate.

Under the NSPS regulations, facilities that were in operation before the dates stated in each of the four subparts are considered “grandfathered” and would not be subject to the newer standards, unless they underwent a major modification.

State Implementation Plans (SIPs). The performance standards above can be enforced by a federal, state, or local regulatory agency. There are additional CAA regulations that could require a coal-fired unit to install a particulate removal device notwithstanding the grandfather clause in Subparts D, Da, Db, and Dc. SIPs may impose, on a state-by-state basis, PM controls of varying stringency on specific sources or categories of sources, including coal-fired utilities. Such controls are required under Title I of the CAA if a particular area is in nonattainment for the NAAQS for a criteria pollutant such as PM. For this reason, SIP controls will generally be more stringent in such nonattainment areas. In attainment areas, the prevention of significant deterioration (PSD) program requires new sources to apply Best Available Control Technology (BACT), which must be at least as stringent as NSPS.

NAAQS for Sulfur Dioxide and Title IV Acid Rain Requirements

Together, the NAAQS for sulfur dioxide and the Title IV Acid Rain Requirements are a factor in the use of FGD technology at coal-fired utilities. Like the NAAQS for PM, the NAAQS for sulfur dioxide establish a maximum concentration of sulfur dioxide in the ambient air. The NAAQS for sulfur dioxide are implemented through NSPS and SIPs. The functioning and applicability of the sulfur dioxide NSPS requirements are similar to those for PM, although there is less variation based on age and size.

Each of the four categories of coal-fired utilities regulated under Subparts D, Da, Db, and Dc is subject to the same requirement: sulfur dioxide emissions must be less than 520 nanograms per joule (ng/J) of heat input. Facilities with greater than 22 MW of heat input capacity generally also must achieve a 10 percent reduction in their sulfur dioxide emissions, based on the potential concentration in fuel. An additional category of coal-fired facilities, those constructed or modified after June 9, 1989, and between 2.9 and 8.7 MW heat input capacity, also must meet the 520 ng/J standard, but may do so based on certification from the fuel supplier that the sulfur content of the fuel is low enough to meet the standards.

In addition to NSPS, states may impose controls through their SIPs to meet the sulfur dioxide NAAQS. These controls may vary in stringency depending on attainment status and may be placed on specific sources or categories of sources, including coal-fired utilities.

The Title IV acid rain provisions provide additional impetus for the application of FGD technology at coal-fired utilities. These provisions require specific reductions of sulfur dioxide emissions via the following:

- Installing FGD equipment
- Switching to low sulfur fuel
- Purchasing emissions allowances from other sources that have exceeded their reduction requirements.

Affected sources are allowed complete flexibility in choosing among these options. The current phase of the Title IV program affects several hundred of the largest generating units at utilities. Between 1992 and 1996, more than half of the affected facilities chose to switch to low sulfur coal in response to the requirements; however, 16 utilities chose to install FGD equipment at 27 generating units accounting for 14,101 MW of capacity (about 5 percent of 1997 utility coal-fired capacity) (EIA, 1997f). This decision contributed to the growth in generation of FGD waste during the period.

EPA is currently evaluating further requirements for lower sulfur dioxide standards and emissions that could increase desulfurization waste generation and/or continue to increase the use of low sulfur coal. EIA projects that an additional 26,400 MW of capacity (about 9 percent of 1997 capacity) will be retrofit with FGD technology in response to the next phase of requirements (EIA, 1998a). FGD waste generation would increase as a result of these retrofits.

NAAQS for Ozone

The NAAQS for ozone establish a maximum concentration of ozone in the ambient air. EPA recently lowered this concentration from 0.12 ppm to 0.08 ppm. The new standard allows four exceedences of the maximum in a region over a 3-year period. EPA expects states will meet the new standard by amending their SIPs to limit nitrogen oxide emissions at utilities. In proposing the new rule, EPA published a Regulatory Impact Analysis (RIA) forecasting changes in the operating practices of utilities that could result from these SIP modifications (EPA, 1997b).[11] As a result of the new regulations, utilities are expected to invest in new combined cycle gas-fired units and oil- or gas-fired combustion turbines rather than coal-fired plants to provide new capacity. Coal-fired capacity is not expected to increase through 2010 (EPA, 1997b). EIA similarly predicts only limited additions to coal-fired capacity through 2010 (EIA, 1998a). Therefore, utility generation of ash is expected to increase more slowly than in the past, even with continued growth in the utility industry.

The RIA also estimates that some existing coal-fired plants will retrofit scrubbers to comply with the regulations. This could result in an increase in FGD waste generation. Also, plants that add scrubbers are expected to switch from low-sulfur Western coal to less expensive Eastern coal, which could result in some changes in waste characteristics (EPA, 1997b).

NESHAP

Under the NESHAP, EPA is required to establish technology-based standards for 189 hazardous air pollutants (HAPs). These standards are to be set on an industrial category basis and will apply to facilities (major sources) that emit greater than 10 tons/year of any one HAP or greater than 25 tons/year of any combination of HAPs.

EPA has studied HAP emissions from utility coal-fired steam generating units and found that mercury from coal-fired utilities is the HAP of greatest concern. Dioxins and arsenic (primarily from coal-fired plants) also are of potential concern. EPA has deferred any determination as to whether regulations to control HAP emissions from utilities are appropriate and necessary. EPA is continuing to collect data on mercury emissions from coal-fired plants (EPA, 1998c). If HAP regulations are promulgated in the future, they could affect the characteristics or quantity of FFC solid wastes.

3.5.2 Regulations Addressing Water Pollution

Under the CWA, the National Pollutant Discharge Elimination System (NPDES) controls discharges to waters of the United States. The controls required under NPDES affect the collection and management of UCCWs. In states authorized by EPA, these controls are implemented through state programs (often termed State Pollutant Discharge Elimination Systems, or SPDES). Because state programs must be at least as stringent as the federal program, the discussion here focuses on federal requirements as a lowest common denominator. NPDES requirements apply differently to two categories of discharges: process wastewaters and stormwater runoff.

NPDES Requirements for Process Wastewaters

The NPDES requirements that apply to process wastewaters from coal-fired utilities are those for the steam electric point source category under 40 CFR Part 423. These requirements apply to facilities "primarily engaged in the generation of electricity for distribution and sale" (i.e., utilities). Under these requirements, each discharge requires an individual NPDES permit with numeric limitations based on Best Practicable Control Technology Currently Available (BPT), Best Available Technology

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[11] The RIA was based on a slightly more stringent ozone standard that allowed only three exceedences over a 3-year period and also incorporated the impacts of proposed changes to the PM standard that have not yet been finalized. Still, the general trends forecast by the RIA are expected to be valid for purposes of this analysis.

Economically Achievable (BAT), or New Source Performance Standards (NSPS). Facilities that discharge to publicly owned treatment works (POTWs) rather than directly to surface waters face Pretreatment Standards for Existing Sources (PSES) similar to BAT or Pretreatment Standards for New Sources (PSNS) similar to NSPS.

For the steam electric point source category, the NPDES process wastewater requirements most relevant to collection and management of large-volume UCCWs are total suspended solids (TSS) limits placed on fly ash handling and bottom ash handling waters. When these UCCWs are managed wet, facilities may have to settle or otherwise remove a certain amount of UCCW from the handling water to meet the TSS limits prior to discharge. Thus, the requirements control the direct release of fly ash and bottom ash to surface waters. In addition, the NSPS include a zero discharge requirement for fly ash handling water. As discussed in Section 3.3, this requirement may be partially responsible for the trend toward dry ash management in newer units.

The NPDES requirements for process water also have elements that are relevant to low-volume combustion wastes. These requirements include technology-based limits on the following waste streams: all waste streams (PCBs and pH); all low-volume wastes (TSS and oil and grease); chemical metal cleaning waste (TSS, oil and grease, copper, iron); once-through cooling water (chlorine); cooling tower blowdown (chlorine, chromium, zinc, 126 priority pollutants); and coal pile runoff (TSS). These requirements control the release of the indicated constituents from management units to surface waters. To meet these limits, facilities may have to treat their low-volume wastes either prior to comanagement or in the comanagement unit.

EPA has reserved NPDES limitations on non-chemical metal cleaning wastes and FGD waters for future rulemakings. Future requirements may affect the characteristics of the low-volume wastes as managed or of the combined wastes.

NPDES Requirements for Stormwater

NPDES stormwater requirements apply to stormwater runoff from FFC facilities (e.g., runoff from operating areas, ash handling areas, waste management units). Facilities can meet these requirements by including stormwater in their individual NPDES permit or seeking coverage under a general permit by submitting a Notice of Intent (NOI). When stormwater discharges are covered under an individual permit, control and monitoring requirements will be facility-specific, subject to the judgment of the permit writer.

When covered by a general stormwater permit, requirements include implementation of a stormwater pollution prevention plan, “reasonable and appropriate” control measures, and 1 or 2 years of monitoring and reporting. No site visit by regulators is required under the general permit. Under the general permit approach, coal-fired utilities have a great deal of flexibility in selecting appropriate control measures for runoff that may have contacted large-volume CCWs. The general permit requirements include recommended best management practices for stormwater at steam electric facilities, landfills, treatment works, and construction areas greater than 5 acres. The requirements are additive across industrial sectors. For example, a utility with an onsite ash landfill must meet both steam electric and landfill requirements.

Because the stormwater program is relatively new and managed only by authorized NPDES states, the number of facilities with general versus individual permits is not known. EPA handles NOIs for 10 nonauthorized states. In these states, 700 steam electric facilities (including non-utility combustors) have filed for general permits.

3.5.3 Regulations Addressing Solid and Hazardous Waste

EPA regulates the management of solid and hazardous waste through Subtitles C and D of RCRA. Subtitle C of RCRA establishes a "cradle-to-grave" management system for wastes that are considered hazardous because they fail tests based on physical and chemical characteristics (i.e., toxicity, corrosivity, ignitability, and reactivity) or because they are listed as hazardous by EPA. Federal regulations establish stringent environmental and administrative controls that must be applied to management of these wastes. Coal-fired utility comanaged wastes are currently exempt from federal regulation as hazardous waste under Subtitle C pending this Report to Congress and the subsequent regulatory determination. Therefore, these wastes are subject to the requirements of Subtitle D of the RCRA as nonhazardous solid waste.

Implementation of Subtitle D is the responsibility of individual states, but nothing prevents states from imposing stringent requirements (including hazardous waste requirements) on FFC wastes. Currently, 44 states (representing 96 percent of utility coal-fired generating capacity) duplicate the federal policy exempting UCCWs from hazardous waste regulations. The other six states (Kentucky, Tennessee, Washington, New Jersey, Maine, and California) do not exempt UCCWs from hazardous waste regulation. In these states, any UCCWs that fail the hazardous waste characteristic tests would be subject to state hazardous waste requirements and managed in units that meet permitting, design, operating, corrective action, and closure standards.

As discussed in Section 3.2, UCCWs seldom fail the hazardous waste characteristic tests. Therefore, the majority of UCCWs would be subject to state requirements under Subtitle D because they do not fail the hazardous waste characteristic tests and/or are generated in the 44 states that duplicate the federal exemption. The 1988 Report to Congress presented data on such state regulations from a 1983 Utility Solid Waste Activities Group survey. Under 1983 regulations, most states required permits for landfills managing UCCWs, at least on a case-by-case basis; however, a smaller percentage of states had the authority to impose physical controls or monitoring requirements on these landfills (see Table 3-23). The 1988 Report to Congress also found that state regulations only "indirectly addressed" waste management in surface impoundments.

More recent data (CIBO, 1997c; EPA, 1995b; ASTSWMO, 1995; ACAA, 1996a) show that the majority of states now have authority to impose physical controls and monitoring requirements on UCCW landfills, at least on a case-by-case basis. Table 3-23 compares state regulatory authority with respect to UCCW landfills reported in the 1988 Report to Congress to current data. Table 3-24 shows data on current state regulatory authority with respect to surface impoundments. No earlier data comparable to that for landfills in the 1988 Report to Congress was available for surface impoundments. Comparing current regulations for surface impoundments with those for landfills, the percentage of states with at least case-by-case regulatory authority is similar for both types of units; however, EPA's examination of case study states, discussed below, found that when states impose requirements on impoundments, they typically do so on a case-by-case basis.

The data in Tables 3-23 and 3-24 show that states currently have more authority to impose controls on UCCW management units than in previous years. In addition to regulatory permits, the majority of states are now able to require siting controls, liners, leachate collection systems, ground-water monitoring, closure controls, daily (or other operational) cover, and fugitive dust controls. EPA believes that the use of such controls has the potential to mitigate risks, particularly ground-water pathway risks, from comanaged waste disposal. The adequacy of this mitigation depends on the extent to which states are exercising their authority in situations in which climate, geology, site-specific conditions, and waste characteristics justify it.

Table 3-23. State Regulatory Controls on UCCW Landfills

	1988 Report to Congress			Current		
	Number of States[b]	Percent of States[c]	Percent of Capacity[d]	Number of States[b]	Percent of States[c]	Percent of Capacity[d]
HW Exemption[a]	43	86%	88%	44	88%	96%
Permit Onsite	41	82%	75%	41	82%	77%
Permit Offsite	49	98%	94%	48	96%	95%
Siting Controls	30	60%	54%	46	96%	92%
Liner	11	22%	24%	43	86%	87%
Leachate Collection Systems	20	40%	31%	42	84%	79%
Ground-Water Monitoring	28	56%	60%	46	92%	89%
Closure Controls	27	54%	59%	45	90%	91%
Cover and/or Dust Controls	Not surveyed			49	98%	96%

[a] Exemption from state hazardous waste regulations for CCWs
[b] Number of states with authority to impose the indicated requirement, either by regulation or on a case-by-case basis
[c] Percent of surveyed states with authority
[d] Percent of surveyed utility generating capacity represented by states with authority
Sources: EPA, 1988; CIBO, 1997c; ASTSWMO, 1995; EPA, 1995b; and ACAA, 1996a

Table 3-24. Current State Regulatory Controls on CCW Surface Impoundments

Hazardous Waste	Number of States[b]	Percent of States[c]	Percent of Capacity[d]
Hazardous Waste Exemption[a]	44	88%	96%
Permit Onsite	45	92%	87%
Permit Offsite	45	94%	88%
Siting Controls	41	87%	81%
Liner	45	92%	91%
Leachate Collection Systems	33	73%	68%
Ground-Water Monitoring	44	96%	94%
Closure Controls	43	91%	88%

[a] Exemption from state hazardous waste regulations for CCWs
[b] Number of states with authority to impose the indicated requirement, either by regulation or on a case-by-case basis
[c] Percent of surveyed states with authority
[d] Percent of surveyed utility generating capacity represented by states with authority
Note: No earlier base year data (similar to that from the 1988 Report to Congress for landfills) were available for surface impoundments.
Sources: CIBO, 1997c; ASTSWMO, 1995; ACAA, 1996a

Section 3.3 of this report found that nearly all of the active UCCW comanagement landfills surveyed are subject to regulatory permits and ground-water monitoring requirements. Just more than half of the surveyed landfills are lined and just under half have leachate collection systems. A lesser percentage of active UCCW comanagement surface impoundments have similar controls. These statistics suggest that states have exercised their authority to impose controls at landfills, and to a lesser extent at surface impoundments. Furthermore, Section 3.3 found increasing trends in the use of liners and ground-water monitoring at newer units, both landfills and surface impoundments. This finding suggests that states are increasingly applying their regulatory authority as new units are introduced. To further examine state implementation of solid waste requirements on UCCW comanagement units, EPA examined in greater detail the regulations applicable in five states: Indiana, Pennsylvania, North Carolina, Wisconsin, and Virginia. These five states account for almost 20 percent of coal-fired utility electrical generation capacity. Table 3-25 summarizes the requirements in each of these five states.

Table 3-25. State Waste Management Requirements Applicable to UCCWs in Selected States

Indiana	
Landfill Requirements	Landfills are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the landfill. Based on available characterization data, most comanaged wastes would be subject to Type III landfill requirements. Requirements for these include clay liner (thickness of 3 feet), siting restrictions, fugitive dust control, weekly cover, soil erosion control, 2-foot clay cap at closure, and revegetation at closure. Leachate collection systems are not required but may be used in some cases to relax the liner thickness requirements. Type I and II landfill requirements are more stringent. Type IV landfills, with less stringent requirements, may receive wastes with leachate concentrations below MCLs.
Impoundment Requirements	Regulations do not dictate any specific design, operating, or ground-water monitoring requirements. Requirements may be imposed on a case-by-case basis in individual permits.
Grandfather Clause	Facilities that existed prior to September 1989 may continue to operate, but any expansions at these facilities must comply with the requirements above.
Pennsylvania	
Landfill Requirements	Landfills are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the landfill. Based on available characterization data, most comanaged wastes would be amenable to Class III landfills. Requirements for these include siting restrictions, a 4-foot attenuating soil base (or 1 foot per 4 feet of waste), fugitive dust control, daily cover, soil erosion control, ground-water monitoring, 2-foot clay cap at closure, and revegetation at closure. Class I and II landfill requirements are more stringent.
Impoundment Requirements	Surface impoundments (including those that store waste for less than 1 year) are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the impoundment. Based on available characterization data, most comanaged wastes would be subject to Class II requirements. Requirements for these include siting restrictions, composite liner, leachate detection system, leachate collection system, minimum freeboard requirements, structural integrity requirements, ground-water monitoring, 2-foot clay cap at closure, and revegetation at closure.
Grandfather Clause	Units permitted prior to July 4, 1992, were required to modify their operations to comply with the above requirements by July 4, 1997. Liner and leachate collection requirements may be modified if the operator could demonstrate that the unit had not caused unacceptable ground-water degradation.
Minefill Requirements	UCCWs must meet TCLP limits for disposal at a Class III landfill. Ground-water monitoring is required.
Soil Amendment Requirements	UCCWs must meet pH limits. State agency notification and runoff and erosion controls required. There are siting limitations.

North Carolina	
Landfill Requirements	Industrial waste landfills must demonstrate that their design will ensure that the state ground-water standards are not exceeded at the compliance boundary. The design criteria for demonstrating this include a composite liner, leachate collection system, and cap at closure. Alternatively, the operator may submit ground-water modeling results that demonstrate, based on hydrologic and climatic conditions and waste characteristics, that the standards will be met.
Impoundment Requirements	Regulations do not dictate any specific design, operating, or ground-water monitoring requirements. Requirements may be imposed on a case-by-case basis in individual permits.
Grandfather Clause	To continue operating after January 1, 1998, landfills operating prior to October 1, 1995, must demonstrate that their original design or proposed design changes will meet the ground-water standards. State has the authority to require design modifications if ground-water modeling methods or results are inadequate.
Wisconsin	
Landfill Requirements	Requirements include clay or composite liners, leachate collection systems, fugitive dust controls, 2-foot clay cap at closure, revegetation at closure, and ground-water monitoring. State may modify the requirements for landfills designed to receive "high-volume" industrial waste, specifically coal ash waste, on a case-by-case basis.
Impoundment Requirements	Surface impoundments must meet siting requirements and have leachate collection systems and liners, unless an exemption is granted by the state. Ground-water monitoring of surface impoundments is optional.
Grandfather Clause	Landfills with plan of operations approved prior to July 1, 1996, are exempt from liner and leachate collection requirements. For landfills constructed prior to February 1, 1988, the state may require ground-water monitoring on a case-by-case basis.
Virginia	
Landfill Requirements	For comanaged wastes, industrial landfills must characterize the wastes entering the unit and submit and abide by a management plan for commingling the wastes. Design requirements include leachate collection systems, run-on controls, liner (1 foot of compacted clay or equivalent), cap at closure, fugitive dust controls, ground-water monitoring. A double liner system in which the primary liner is synthetic may be used in lieu of ground-water monitoring. For fly ash and bottom ash from the combustion of fossil fuels, periodic cover or dust control measures such as surface wetting or crusting agents are required. Industrial landfills must conduct ground-water monitoring.
Impoundment Requirements	Monitoring required. No other specific design or operating requirements. Requirements may be imposed on a case-by-case basis in individual permits. Impoundments may be closed with waste in place only if the closure requirements are established in the facility's permit. Otherwise, regulations require (1) removal of all liquids, wastes, and system components at closure, or (2) stabilization of remaining wastes, installation of a cover, and post-closure ground-water monitoring.
Grandfather Clause	Landfills permitted prior to 1988 must submit a monitoring plan but may continue operating without retrofits as long as they do not expand.
Minefill Requirements	Use in structural fills, mine reclamation, or mine refuse disposal requires notification and development of design, operation, and closure plans. UCCWs thus used must not exceed the toxicity characteristic levels for metals. Fugitive dust and run-on and runoff controls and 18 inches of cover at closure required.
Soil Amendment Requirements	Agricultural uses of CCW are exempt from the solid waste regulations provided they meet the requirements of the Virginia Department of Agriculture and Consumer Services.

Based on this analysis, it appears that state requirements have become increasingly stringent over time. States vary in their approaches to regulating UCCW landfills. For example, the Indiana and Pennsylvania programs impose requirements tailored to the characteristics of the waste. North Carolina may impose requirements based on site-specific modeling. In Virginia, requirements apply generically to all industrial wastes. Wisconsin may modify its requirements specifically for landfills designed to receive coal combustion ash. In several of the states studied, UCCWs may be disposed of in landfills that are "grandfathered" out of requirements imposing design requirements such as liners. Regulations in many of the states studied do not impose specific design requirements on surface impoundments that comanage UCCWs. When these states impose requirements on impoundments, they typically do so on a case-by-case basis.

3.6 WASTE MANAGEMENT ALTERNATIVES

Comanaged Wastes in General

The risk assessment in Section 3.4 identified potential ground-water pathway risks to human health from comanaged waste in unlined management units. Mitigation of these potential risks might be accomplished through the use of technologies that prevent or contain and collect leachate from comanaged waste landfills and surface impoundments. Specifically, EPA identified the combination of technologies in Table 3-26 as an alternative that would be practical and effective to target and mitigate the potential ground-water risk. The technologies identified in the table are considered further in the cost and economic impact analysis. These technologies also are consistent with those required under Subtitle D of RCRA. Other risk mitigation approaches (not considered in Section 3.7) might incorporate different design and operating standards for existing landfills and surface impoundments different from those established for new landfills and surface impoundments containing the same wastes. Also, such approaches might include an exemption for certain units that can demonstrate they pose no threat to human health or the environment. For example, when EPA implemented design-based standards for Subtitle C hazardous waste surface impoundments, an exemption was allowed for certain surface impoundments, provided that these impoundments could demonstrate that alternative design and operating practices, together with location characteristics, would prevent the migration of hazardous constituents into ground or surface water at least as effectively as liners and leachate collection systems.

Comanaged Mill Rejects/Pyrites

Coal mill rejects (and particularly their pyrite component) have been identified as a low-volume waste of particular concern (see Sections 3.1, 3.2, and 3.4.3). Because EPA currently is evaluating voluntary industry guidance for mill rejects management, alternatives for this waste stream are not evaluated here.

Agricultural Use and Minefilling

Of the beneficial uses discussed in Section 3.3.5, agricultural use may be of environmental concern, based on the non-ground-water risk assessment that found potential arsenic risks to human health from this practice. An approach for mitigating this potential risk might include a standard limiting the arsenic concentration in wastes intended for this use. Because of the small quantity of waste that would be affected by such an alternative, EPA has not estimated cost for such an approach. Minefilling also may be of concern, particularly when wastes are placed below the water table. EPA is seeking further information on this practice.

Table 3-26. Management Alternatives for Coal-Fired Utility Comanaged Waste and Segregated Mill Rejects

Landfill	Impoundment
Comanaged Waste	
Design includes filter fabric, 1' sand layer, 2' clay liner, synthetic liner (high-density polyethelene [HDPE]), leachate collection system, and ground-water wells. Operation includes environmental monitoring, leachate collection and treatment. Closure requirements include 6" topsoil and vegetation, filter fabric, 1.5' sand layer, 2' clay layer, synthetic liner, and a cover drainage system. Post-closure includes environmental monitoring, landscape maintenance, slope maintenance, inspection, and administration.	Design includes filter fabric, 1' sand layer, 2' clay liner, synthetic (HDPE) liner, leachate collection system, and ground-water wells. Operation includes environmental monitoring, leachate collection and treatment. Closure requirements include 6" topsoil and vegetation, filter fabric, 1.5' sand layer, 2' clay layer, synthetic (HDPE) liner, added fill to achieve slope, and cover a drainage system. Post-closure includes environmental monitoring, landscape maintenance, slope maintenance, inspection, and administration.

3.7 COMPLIANCE COSTS AND ECONOMIC IMPACTS

This section discusses the costs and economic impacts of risk mitigation alternatives for coal-fired utility comanaged wastes. Details of this analysis, together with a background describing this complex industry, are documented as part of the EPA docket.

3.7.1 Overview and Methodology

In estimating costs and economic impacts for comanaged waste at coal-fired utilities, EPA relied on the descriptive information for this sector presented previously in this chapter. Salient features are reviewed below. It is important to bear in mind as these costs and impacts are reviewed that this industry is large, generating more than $200 billion in sales annually.

EPA's analysis began with the 353 coal-fired plants identified in the 1993 U.S. Department of Energy (DOE) Energy Information Administration (EIA) 767 database that have electrical generation capacities of at least 10 MW. This was supplemented by data (e.g., the frequency of comanagement, the frequency of landfills and impoundments, waste generation rates) provided by the industry and discussed in previous sections of this chapter. The Agency recognizes that there are uncertainties in working with a database of this magnitude; the cost uncertainty discussed below reflects this.

EPA estimated the incremental compliance cost of the risk mitigation alternative for comanaged waste described in Section 3.6.[12] As described in that section, this requires generators to construct composite-lined landfills and impoundments for comanaged wastes. The cost estimate summed the costs of five categories: initial capital costs, recurring capital costs, annual operating and maintenance costs, closure costs, and annual post-closure costs. Table 3-27 identifies the specific components included in each cost category.

[12] Because the Agency currently is evaluating a voluntary industry proposal for mill reject management, costs for mill rejects alternatives are not considered here.

Table 3-27. Cost Components Included in Landfill and Impoundment Designs

Category	Landfill Cost Components	Impoundment Cost Components
Initial Capital Costs	Land purchase Site development Excavation Filter fabric 1' sand 2' clay liner Synthetic (HDPE) liner Leachate collection Ground-water wells Indirect capital costs	Land purchase Site development Excavation Filter fabric 1' sand 2' clay liner Synthetic (HDPE) liner Leachate collection Ground-water wells Indirect capital costs
Recurring Capital Costs (5-yrs)	Heavy equipment (dump truck, bulldozer, sheepsfoot roller, water truck) Indirect capital costs	Not applicable
Annual O&M Costs	Heavy equipment operation Environmental monitoring Leachate collection and treatment	Environmental monitoring Leachate collection and treatment
Closure Costs	6" topsoil and vegetation Filter fabric 1.5' sand 2' clay Synthetic (HDPE) liner Cover drainage system Indirect closure costs	6" topsoil and vegetation Filter fabric 1.5' sand 2' clay Synthetic (HDPE) liner Added fill to achieve slope Cover drainage system Indirect closure costs
Annual Post-Closure Costs	Environmental monitoring Landscape maintenance Slope maintenance Inspection Administration	Environmental monitoring Landscape maintenance Slope maintenance Inspection Administration

For these comanaged utility wastes, the cost estimate was based on opening new management units to replace existing landfills and impoundments that currently do not meet the requirements described in Section 3.6. Because of this, the estimate included the costs of the purchase of land to site new units where required.

Variations on this approach might substantially reduce the total costs incurred. For example, EPA might allow existing impoundments to be used as is for a period (say, 10 years) and only then drained, dredged, and lined in place. Such approaches would reduce the total (discounted) compliance cost by both deferring cost and reducing the number of units above baseline to be lined. The Agency has not yet estimated the cost of such variations, but anticipates a significant reduction below the $800 to $900 million annual total shown below (possibly by some 50 percent).

The cost estimate utilized unit cost data from engineering cost literature and vendor quotation to develop costs for three different landfill and impoundment sizes. The three sizes were defined to characterize the range of management unit sizes (i.e., capacity, area, depth) observed in practice. Table 3-28 provides insight into design features that underlie this costing.

Table 3-28. Design Parameters Assumed for Small, Medium, and Large Landfills and Impoundments

Parameter		Landfill	Impoundment
Sizes (tons/year)	small	9,650	7,220
	medium	96,500	72,200
	large	965,000	722,000
Depth (feet)		Pile design	
	small	1.0	10.0
	medium	1.0	20.0
	large	3.0	20.0
		Combination fill design	
	small	10.0	
	medium	31.0	
	large	58.6	
Height (feet)		Pile design	
	small	25.0	0
	medium	30.5	0
	large	79.4	0
		Combination fill design	
	small	14.8	
	medium	40.5	
	large	79.4	
Area (acres)		Pile design	
	small	13.5	21.4
	medium	239.1	106.3
	large	479.2	1,023
		Combination fill design	
	small	13.0	
	medium	44.1	
	large	228	

Note: Landfill designs considered include a “pile design” constructed primarily above grade and a “combination fill design” constructed both above and below grade.

Using regression analysis, these were converted to data supporting a single cost equation. Annualized costs were then estimated as a function of waste generation rate on a plant-specific basis. Total industry costs were derived by summing the plant-specific cost estimates derived for the 353 identified coal-fired plants.

Using the methodology described above, the Agency developed costs and economic impacts as set forth in the following three sections: incremental compliance cost, compliance cost impact on plants as a function of plant size, and industry impact. Incremental compliance costs are the costs of risk mitigation practices *over and above* the cost of current management practices. (Thus, for those facilities currently meeting the requirements described in Section 3.6, incremental costs are zero.) Using incremental compliance costs as an indicator of potential cost burden, the analysis examined impacts on individual plants as a function of plant size. This was performed using pro forma financial statements for three representative plant sizes as a basis against which to compare incremental compliance costs. For industry impact evaluation, the use of econometric models to perform the analysis was considered and rejected. The primary reason for this was that partial equilibrium analysis at this time would imply a level of precision that cannot be supported, given the uncertainty surrounding ongoing deregulation of the industry. The industry-level analysis thus focuses on two measurements to assess economic impact: the number of affected facilities and the magnitude of incremental compliance costs relative to the value of electricity sales. These are used to build to an indication of the effect on supply and demand relationships and possible impact on price.

3.7.2 Incremental Compliance Cost

Key variables in estimating incremental compliance cost were the number of affected plants, current management practices (i.e., the number currently meeting the requirements described in Section 3.6), estimated waste generation quantities, and costs of key components (e.g., liners). All of the estimates shown assume a 40-year operating life for management units.

EPA's estimate of incremental compliance cost is some \$860 million per year, using the most likely values for all the input variables. If all variables were to combine at either the high or low end, a much wider range of incremental compliance cost would result. It is EPA's judgment, however, that the likely range would be \$800 to \$900 million per year, based on reasonable estimates of uncertainty in the input variables and the low probability that all variables would combine at either their high- or low-end values.

In the estimates above, liner construction accounts for most of the estimated cost. Liner construction costs are driven by the area to be covered, which makes the incremental unit costs for impoundments higher because of their large area-to-depth ratio. Also, the smaller percentage of impoundments currently estimated to be lined (see Section 3.3.4) increases the total incremental cost for impoundments.

Note that the costs above are incremental (above current costs). Annual costs were discounted at 7 percent to 1998 dollars based on Office of Management and Budget (OMB) guidance, with no inflation built into out-year estimates. Also, it was presumed that compliance would be required immediately, and that amortization would take place over 40 years for both landfills and impoundments.

3.7.3 Compliance Cost Impact on Plants as a Function of Plant Size

A full analysis of the potential for deregulation to affect this analysis was considered but not undertaken because of resource limitations and the high degree of uncertainty associated with deregulation. EPA recognizes that such an analysis might show impacts different from those presented below.

EPA believes that the ability of industry to pass through cost increases will be limited for two general reasons. First, large portions of the electric power generation industry would not be directly affected (e.g., nuclear power plants) and thus opportunities to pass on costs will be limited. Second, the electric utility industry is rapidly changing from a regulated, regional market structure to an open and presumably competitive multiregional (if not national) market. This may reduce the potential to pass on increased costs. Therefore, this analysis includes no analytical consideration of price effects.

Economic impacts at the plant level will depend on several major factors, including quantity of fuel used, quality of fuel, profitability, and production technology. To assess these impacts across the range of plants, EPA estimated financial data for model plants representing three size ranges: large (burning greater than 1.5-million tons of coal per year), medium (burning between 750,000 and 1.5-million tons of coal per year), and small (burning less than 750,000 tons of coal per year). The large and medium model facilities are representative of investor-owned utilities and the small facility is more representative of a publicly owned utility. Table 3-29 compares incremental compliance costs to revenues and net income for these three model plants. The incremental compliance costs used in this analysis reflect EPA's best estimate based on most likely values of the relevant input variables.

Table 3-29. Plant-Level Impact of Incremental Compliance Costs

	Large Coal Plant Investor-Owned Utility		Medium Coal Plant Investor-Owned Utility		Small Coal Plant Publicly Owned Utility	
	$1,000's	Percent of Revenues	$1,000's	Percent of Revenues	$1,000's	Percent of Revenues
Revenues from Electricity	426,000	100%	142,000	100%	60,000	100%
Baseline Before Tax Net Income	55,380	***13.0%***	18,400	***13.0%***	5,400	***9.0%***
Expected Incremental Compliance Costs (replace unlined management unit with composite-lined unit)	6,165	1.5%	2,197	1.6%	1,285	2.1%
Expected Post-Compliance Net Income	49,215	***11.5%***	16,203	***11.4%***	4,115	***6.9%***

The incremental compliance cost for comanaged wastes should not impact the financial viability of coal-fired plants. This appears true even for plants transitioning from the worst case unlined management unit to a composite-lined unit. For example, a large, investor-owned utility (IOU) coal-fired plant with more than 1,000 MW of generating capacity is estimated to comply for about $6.16 million per year (or about $16 per ton of waste). Based on typical annual revenues and cost, compliance costs would

increase overall costs by 1.5 percent of revenues. Without any price adjustments, net income before taxes for this investor-owned plant would be reduced from about 13 to 11.5 percent and remain at more than $49 million per year. EPA recognizes that such profit margin reductions may be considered significant by the individual utility.

Financial impacts on a medium-sized IOU coal-fired plant with about 370 MW of generating capacity suggest it should also remain financially viable. Costs would increase by about 1.6 percent of revenues, with profitability (before tax) at about 11.4 percent of revenue, with net income after compliance of more than $16 million per year. (Incremental compliance costs are estimated at about 18.31 per ton of comanaged waste, or about $2.2 million per year.)

Because of higher unit compliance costs and lower net income margins, smaller, publicly owned coal-fired plants would incur relatively higher impacts. For example, an average small publicly owned plant with about 180 MW of capacity is estimated to comply for about $1.3 million per year (about $25.70 per ton of comanaged waste). Based on typical revenues and costs, compliance costs for a small coal-fired utility would increase overall costs about 2.1 percent. This would reduce net income, without price adjustments, from about 9 percent to 6.9 percent of revenue, or to about $4 million per year.

Table 3-30 shows how the estimated population of affected facilities breaks down by the three size categories represented by the model plants. It also compares the incremental compliance costs estimated for the model plants to average sales for individual plants in each size category. As noted above, incremental compliance costs range from 1.5 percent of sales for large plants to 2.1 percent of sales for small plants.

Table 3-30. Incremental Compliance Cost by Plant Size

Size Category	Number of Plants	Percent of Plants	Plant Sales ($million/year)	Compliance Cost ($million/year)	Percent of Sales
Large (>1.5-million tons/year of coal)	148	42%	$426	$6.2	1.5%
Medium (750,000 to 1.5-million tons/year of coal)	61	17%	$142	$2.2	1.6%
Small (<750,00 tons/year of coal)	144	41%	$60	$1.3	2.1%

3.7.4 Industry Impacts

As noted, the U.S. electric power industry is entering an era of major restructuring. Given the uncertainty surrounding this restructuring, the use of econometric models to perform the industry impact analysis was rejected. Partial equilibrium analysis at this time would imply a level of precision that cannot be supported, given the uncertainty surrounding ongoing deregulation of the industry. The total cost of compliance compared to total industry sales, however, should still serve as a good proxy for estimating industry effects.

The electric power generating industry, including fossil fuel, hydroelectric, nuclear, and other fuel sources, was a $212 billion per year industry in 1996. To provide perspective on the possible incidence of compliance cost, the following characteristics of the electric utility industry are noted:

- An average price to consumers of 6.86 cents per kilowatt hour (kWh) in 1996, which can vary from less than 3 cents per kWh for industrial customers of a federal utility to more than 15 cents per kWh for residential customers of a northeastern investor-owned utility
- Annual electricity consumption of 3,120 billion kWh (1997) or 11,860 kWh per capita
- Approximately 3,200 entities selling electricity with industry ownership, including the following:
  - 243 investor-owned utilities (7.6 percent of all utilities) producing 76 percent of U.S. electricity sales (2,343 billion kWh and $167 billion or $687 million per entity)
  - 2,014 smaller public utilities (mainly municipalities and other local government entities and 63 percent of all utilities) producing only 14.5 percent of the electricity sales (451 billion kWh and $27 billion or $13 million per entity)
  - 932 cooperatives (29 percent of all utilities) producing 8 percent of industry sales (241 billion kWh and $17 billion or $18 million per entity)
  - 10 federal utilities (0.3 percent of all utilities) accounting for 0.6 percent of electricity sales (50 billion kWh and $1.3 billion or $130 million per federal utility)
- Increasing trends in the use of coal and declining trends in the use of oil, as discussed in Chapter 2 of this report.

Based on the best estimate of costs presented above, the electric utility industry would incur about $860 million in incremental annualized compliance costs. As shown in Table 3-31, this would represent 0.4 percent of the industry's value of shipments. It would be concentrated in the coal-fired utility component, which accounts for about 56 percent of all electricity generated in the United States. Individual operators likely would take this effect into consideration, along with several other factors, in assessing how soon to close marginal coal plants and what type of new plants to build. This implies that a possible effect of the identified risk mitigation alternative would be a shift to alternative energy sources.

Table 3-31. Industry Economic Impacts, Coal-Fired Utility Comanaged Wastes

Industry Sales ($ million/year)	Compliance Cost ($ million/year)	Percent of Sales
$212,000	$862.4	0.4%

The high cost of compliance reflecting this mitigation action is but a very small percentage of revenues. If, as noted at the start of Section 3.7, above, a risk mitigation strategy embodying allowance for continuing but phased-down utilization of existing impoundments and landfills is considered, this percentage of revenues would be driven even lower; perhaps down to as low as 0.2.

Coal-fired plants might attempt to pass costs to consumers in the form of higher prices. This would be restricted by competition from unaffected plants (i.e., hydroelectric and nuclear). Investor-owned utilities, representing only about 8 percent of utility operators, would be the major determinants of price effects as they control about 80 percent of electric energy sales (as well as the majority of large coal-fired plants). Investor-owned utilities also are merging and consolidating operations rapidly and will be the primary players in a more open and national electricity market.

3.8 FINDINGS AND RECOMMENDATIONS

3.8.1 Introduction

Based on the information collected for this Report to Congress, this section presents a summary of the Agency's main findings presented under headings that parallel the organization of this chapter. It then presents the Agency's tentative conclusions concerning the disposal and beneficial uses of comanaged wastes generated at coal-fired utilities, including wastes from the burning of petroleum coke and the coburning of other fuels with coal as identified in this chapter.

3.8.2 Findings

Sector Profile

- There are about 450 coal-fired power plants located throughout the United States. Most states have at least one coal fired utility plant. The eastern United States has a larger concentration of plants than the western United States.

- There are approximately 1,250 coal-burning boilers in operation at coal-fired power plants. A particular plant can have multiple boiler (generating) units.

- Coal-fired power plants account for more than 50 percent of the electricity produced in the United States. There is a wide range of electrical generating capacity represented in the population of power plants. Coal-fired plants can range in size from less than 50 megawatts (MW) to more than 3,000 MW. The amount of wastes generated at these plants is generally proportional to the amount of electricity generated.

- Coal-fired power plants are located in diverse environments. Power plants are located in areas that vary widely in population density, geography, precipitation, and general climate. Two common factors in siting coal-fired plants are (1) location near a major body of surface water, such as a lake or river as a source of cooling water, and (2) locating to accommodate economical transport of the large amounts of coal required to generate electricity.

Waste Generation and Characteristics

- About 105-million tons of large volume coal combustion wastes (i.e., fly ash, bottom ash, boiler slag, flue gas desulfurization [FGD] sludge) are generated annually at coal-fired power plants.

- Utilities generate a variety of low-volume wastes that result from supporting processes that are ancillary to, but a necessary part of, the combustion and power generation process. Examples include coal pile runoff, boiler blowdown, and boiler chemical cleaning wastes.

- The total amount of the numerous low-volume wastes generated at these plants is not well established, but estimates vary from less than one-half to several times the amount of large-volume wastes. Most of the low-volume wastes are aqueous. Water comprises a substantial portion of the aqueous low-volume wastes.

- The constituents of concern in the large-volume wastes are trace elements, metals in general, and the eight RCRA metals in particular. No organic constituents, including dioxins, and no radionuclides were identified at potential levels of concern in these wastes.

- The large-volume and low-volume wastes are managed in many different combinations. Metals are the only class of constituents of concern in the comanaged wastes.

- A few of the individual low-volume wastes, such as boiler chemical cleaning wastes and demineralizer regenerant, occasionally test as characteristically hazardous for toxicity and/or corrosivity; however, none of the comanaged waste mixtures tested characteristically hazardous for corrosivity, reactivity, or ignitability. There were no toxicity characteristic exceedences observed in TCLP samples of comanaged wastes, although there were infrequent exceedences observed in some *in situ* pore water samples.

Waste Management Practices

- An estimated minimum of 80 percent of the large-volume wastes are comanaged with low-volume wastes. (The comanaged wastes are the subject of this chapter.)

- The most frequent industry practice for comanaged wastes is disposal in landfills or surface impoundments. There are approximately 600 of these waste management units serving coal-burning power plants, with nearly equal numbers of landfills and impoundments. Most impoundments and about half of the landfills are located at the generating site.

- The waste management units are large in scale, typically 60 acres for a landfill and 90 acres for an impoundment. There is an increasing industry trend to use landfills instead of impoundments for disposal, due partly to Clean Water Act new source regulations that encourage dry handling of fly ash by setting a zero wastewater pollutant discharge standard.

- The utility sector in recent years has increasingly installed more environmental controls for comanaged waste facilities. Prior to 1975, fewer than 20 percent of the waste management units (landfills and impoundments) were lined. Today, more than one-half of the landfills and one quarter of the impoundments are lined. Other examples of in-place controls include leachate collection, ground-water monitoring, and operation under regulatory permits, each of which has a high rate of implementation at landfill management units, and significant implementation at surface impoundment management units.

- A significant portion of these wastes are reused. Nearly 27 percent of the large-volume wastes are currently managed through beneficial uses. Some portion of these reused wastes are actually comanaged wastes. The potential for increased reuse of these wastes currently appears to be limited, based on demand for the products and services where the wastes are used.

Potential Risks and Damage Cases

- EPA conducted a risk assessment that found a lack of potential human health risk for virtually all waste constituents. Arsenic was the one constituent for which the Agency identified potential human health risks via the ground-water pathway where these wastes are managed in unlined landfills and surface impoundments. The identified risk is based on high-end risk scenarios in EPA's risk modeling analysis for human ingestion of well water influenced by releases from the waste management unit. The time to reach the health-based level for arsenic in ground water at the receptor well is about 500 years for the modeled surface impoundment case and in excess of 3,500 years for the modeled landfill case.

- EPA conducted a risk assessment that found a lack of potential human health risk for virtually all waste constituents. Arsenic was the one constituent for which the Agency identified potential human health risks via non-ground-water pathways where these wastes are used as soil amendments for agricultural purposes. The identified risk is based on high-end risk scenarios in EPA's risk modeling analysis, for human ingestion exposure routes.

- Based on hypothetical exposure scenarios, the Agency identified potential ecological risks where these wastes are managed in surface impoundments from selenium (mammals), although potential risks were also found from arsenic (birds), aluminum (amphibians), and boron (amphibians). This is based on direct exposure of the receptors to the waters in surface impoundments.

- The Agency identified a total of six damage cases associated with management of these wastes. Each case involved older, unlined waste management units. The releases in these cases were basically confined to the vicinity of the facilities and did not affect human receptors. None of the damages caused effects on human health.

- Damage cases and other problem management cases are dominated by chronic incidents, such as leaks and occasional runoff as opposed to catastrophic incidents, such as sudden releases or spills.
- If not managed properly, pyritic wastes (in mill rejects) have the potential to generate acid that can mobilize constituents in the comanaged wastes and contribute to risk.

- The Agency has very limited information with which to conduct a risk assessment on the practice of minefilling the comanaged wastes and, therefore, cannot quantify the risks associated with this practice at this time. Minefilling includes disposal of wastes by placement in mine voids and placement of wastes in mine voids for reclamation purposes.

- Some natural arsenic levels in U.S. soils have the potential to pose higher risks than the risk identified with the level of arsenic that may be contributed by these wastes for non-ground-water pathways.

Existing Regulatory Controls, State and Federal Requirements

- The utility industry has a significant level of installed environmental controls for these wastes, and is increasingly implementing control measures that mitigate the potential human health risks identified in this study.

- States increasingly have begun to impose controls on coal combustion waste management units. The majority of states now have regulatory permit programs (45 states) as well as the authority to require siting controls (41), liners (45), leachate collection systems (33), ground-water monitoring (44), and closure controls (43) for management of these wastes. Many states also have authority to require daily or other operational cover and fugitive dust controls.

- There are significant existing federal environmental controls that affect waste management practices in this sector. These include new source performance standards under the Clean Water Act that encourage dry fly ash handling, which has likely contributed to the recent industry trend away from the use of wet ash handling (sluicing ash) to impoundments. Significant federal authorities also exist to address site-specific problems and damages at existing waste management sites under RCRA Section 7003 and CERCLA Sections 104 and Section 106, when situations pose threats to human health and the environment.

- The rate of environmental compliance inspections at fossil fuel electric power generation facilities is among the highest for any industrial sector. Moreover, the rate of enforcement actions compared to the inspection rate is among the lowest for any industrial sector. Since 1992, there have been about 13 major environmental cases involving fossil fuel electric power generating facilities, none of which was for violations directly related to management of solid or hazardous wastes.

Potential Costs and Impacts of Regulation

- The Agency estimates that the total annual incremental compliance costs for mitigation of the potential arsenic risks identified in this study would be between $800 and $900 million (1998$). These costs represent replacement of existing unlined management units with lined management units, and implementing ground-water monitoring and leachate collection and treatment. These measures do not represent implementation of full Subtitle C requirements, but rather modifications of such requirements that could potentially be adopted under Section 3004(x) of RCRA.

- If these wastes were to be regulated under full Subtitle C, virtually all existing facilities would be required to invest substantial funds and resources to modify existing management practices. The total annual cost of full Subtitle C requirements would considerably exceed the $800- to $900-million (1998 $) estimate above.

- If beneficial uses of these wastes were subject to any regulation under Subtitle C, possibly all beneficial use practices and markets would cease.

- The cost of compliance with RCRA Subtitle C by coal-burning power producers could reduce the amount of coal consumed in favor of other fuels. Depending on the extent of specific Subtitle C regulation, the cost of generating electricity by burning coal could substantially increase.

3.8.3 Recommendations

Following are the Agency's recommendations for the wastes covered in this chapter. The recommendations are based on EPA's analysis of the eight Congressionally mandated study factors (Section 1.2). These conclusions are subject to change based on continuing information collection, continuing consultations with other government agencies and the Congress, and comments and new information submitted to EPA during the comment period and any public hearings on this report. The final Agency decision on the appropriate regulatory status for these wastes will be issued after receipt and consideration of comments as part of the Regulatory Determination, which will be issued within 6 months.

1. *The Agency has tentatively concluded that disposal of these wastes should remain exempt from RCRA Subtitle C.*

The Agency has tentatively concluded that the comanaged wastes generated at coal-fired utilities, including petroleum coke combustion wastes as well as wastes from other fuels co-fired with coal, generally present a low inherent toxicity, are seldom characteristically hazardous, and generally do not present a risk to human health and the environment. Current management practices and trends and existing state and federal authorities appear adequate for protection of human health and the environment. State programs increasingly require more sophisticated environmental controls, and tend to focus on utility waste management due to the high waste volumes. For example, the frequency of environmental inspections at utilities is among the highest of all the major industry sectors in the United States. Most of the landfills and 40 percent of the impoundments implement ground-water monitoring, reflecting the states' focus on this industry sector. In addition, the Agency has identified relatively few damages cases. Although one damage case identified arsenic as a constituent of concern, none of the damage cases affected human receptors. These types of facilities are typically located in areas of low population and thus present infrequent opportunity for human exposure. The industry trend, as detailed in this chapter, is to line waste disposal units and to use dry ash handling techniques at new facilities; dry ash handling eliminates the use of impoundments for waste management. Currently, more than one-half of the active landfills are lined. Although one-quarter of all existing active impoundments are lined, about 45 percent of the impoundments constructed since 1975 have been lined.

If these wastes were listed as hazardous, and therefore regulated under Subtitle C, coal combustion units would be required to obtain a Subtitle C permit, which would unnecessarily duplicate existing State requirements, and would establish a series of waste unit design and operating requirements for these wastes that would most often be in excess of requirements to protect human health and the environment. The estimated total annual cost to mitigate the potential arsenic risk identified in this study exceeds $800 million. This cost does not represent implementation of full Subtitle C controls, but rather Subtitle C requirements modified by RCRA 3004(x) factors to target the identified risks. The Agency estimates that the total cost of full Subtitle C controls would be several times this amount. Full Subtitle C controls include location restrictions, manifesting, liners, leachate collection, ground-water monitoring, covers, dust control, closure controls, financial assurance, and corrective action.

For these reasons, EPA tentatively concludes that Subtitle C is inappropriate to address any problems associated with disposal of these wastes and that the continued use of site and region specific approaches by the states is more appropriate for addressing the limited human health and environmental risks that may be associated with disposal of these wastes. For the issues discussed below involving agricultural use and management of these wastes in mines (minefill), the Agency is still considering whether some regulation under RCRA Subtitle C may be warranted.

The Agency identified several situations where pyrite materials (sulfur-bearing components of mill rejects) comanaged with coal combustion wastes might have been of concern. The pyritic waste materials had turned acidic and may have caused localized environmental damage. One such situation is considered to be a damage case. While mismanagement of these pyritic wastes can theoretically cause problems because of their inherent chemical properties, such evidence is rare, and the Agency has no means of systematically evaluating the extent to which they would cause or contribute to risks. To address the problem management situations, the Agency has engaged the utility industry in a program to ensure that these particular wastes are appropriately managed, as reflected in the industry's development of technical guidance and an industry education program concerning proper management of pyritic materials. The Agency is encouraged by the industry program, and has tentatively concluded that additional regulation of pyrite disposal is not necessary. EPA, however, will follow-up with oversight on the industry's progress with management of these wastes, and will revisit this issue if necessary.

The Agency identified potential ecological risks from selenium (mammals), although potential risks were also found from arsenic (birds), aluminum (amphibians), and boron (amphibians) for coal combustion wastes that are comanaged in surface impoundments. While the waters in surface impoundments can theoretically pose risks to birds, mammals, and amphibians exposed to them, the Agency has no actual information about the scale and frequency at which receptors are actually exposed, and therefore cannot quantify the magnitude of the actual ecological impacts at these facilities. No documented or anecdotal ecological impact information was available with which to compare with the risk modeling results. Moreover, the Agency was unable to identify any feasible risk mitigation practices for these very large impoundments other than to continue to rely on the Clean Water Act new source standards to move the industry toward dry handling of the coal combustion wastes. (Dry handling methods do not involve surface impoundments and therefore do not present the ecological risks identified for impoundments.) Outright elimination of the large impoundments would impose extremely high costs on the operators. The benefits to be derived from elimination of impoundments are uncertain due to unavailability of information on actual receptor exposure rates and impacts as described above. The Agency solicits information on the practices and techniques that may be effective in mitigating the potential ecological risks, considering the large surface areas involved at these facilities.

2. *The Agency has tentatively concluded that most beneficial uses of these wastes should remain exempt from RCRA Subtitle C*.

No significant risks to human health and the environment were identified or believed to exist for any beneficial uses of these wastes, with the possible exception of minefill and agricultural use as discussed below. This is based on one or more of the following reasons for each use or resulting product: absence of identifiable damage cases, fixation of the waste in finished products which immobilizes the material, and/or low probability of human exposure to the material.

3. *The Agency is tentatively considering the option of subjecting practices involving the use of these wastes for agricultural purposes (i.e., as a soil nutrient supplement or other amendment) to some form of regulation under Subtitle C.*

As mentioned above, the Agency identified potential risk from exposure to arsenic in these wastes when they are used for agricultural purposes. The risks identified with this practice are of sufficient concern to consider whether some form of control under Subtitle C is appropriate, given the increasing trend for use of these materials as agricultural amendments. An example of such controls could include regulation of the content of these materials such that arsenic concentrations could be no higher than that found in agricultural lime. On the other hand, imposition of controls under Subtitle C may not be warranted if sufficient protection may be afforded by the Agency engaging the industry to establish voluntary controls on this practice. An example of such voluntary controls could consist of an agreement to limit the level of arsenic in these materials. The Agency solicits comment on its tentative conclusion and specific approaches that could be pursued to address the concern. While the part 1 regulatory determination exempted all beneficial uses for the large-volume coal combustion wastes, the tentative conclusion for the comanaged wastes would also affect the status of the part 1 wastes for agricultural use. This is because the source of the identified risk is the metal content of the coal combustion wastes. The Agency has no information indicating that any of the comanaged low-volume wastes significantly affect the identified potential risks and, therefore, the risks should be comparable for the wastes subject to the part 1 regulatory determination. Additionally, the Agency considers its current risk analysis for this practice to be more thorough than that conducted for the part 1 wastes, and accordingly believes it proper to reconsider the part 1 wastes in this respect.

As indicated in the summary above, although the practice of minefilling these wastes is within the scope of this study, the Agency currently lacks sufficient information with which to adequately assess risk associated with this practice. Several factors make the practice of minefilling difficult to assess. First, minefill is occurring in areas where there are often pre-existing environmental concerns, such as acid mine drainage. With its existing data the Agency is unable to determine if elevated contaminants in ground water are due to minefill practices, or rather are associated with pre-existing problems or conditions. Second, although minefill in a surface pit has similarities to landfill situations we have modeled, both surface and subsurface minefill raises complexities beyond the landfill model. Third, these operations, with their pre-existing concerns, may require very site-specific determinations that do not lend themselves to national standards.

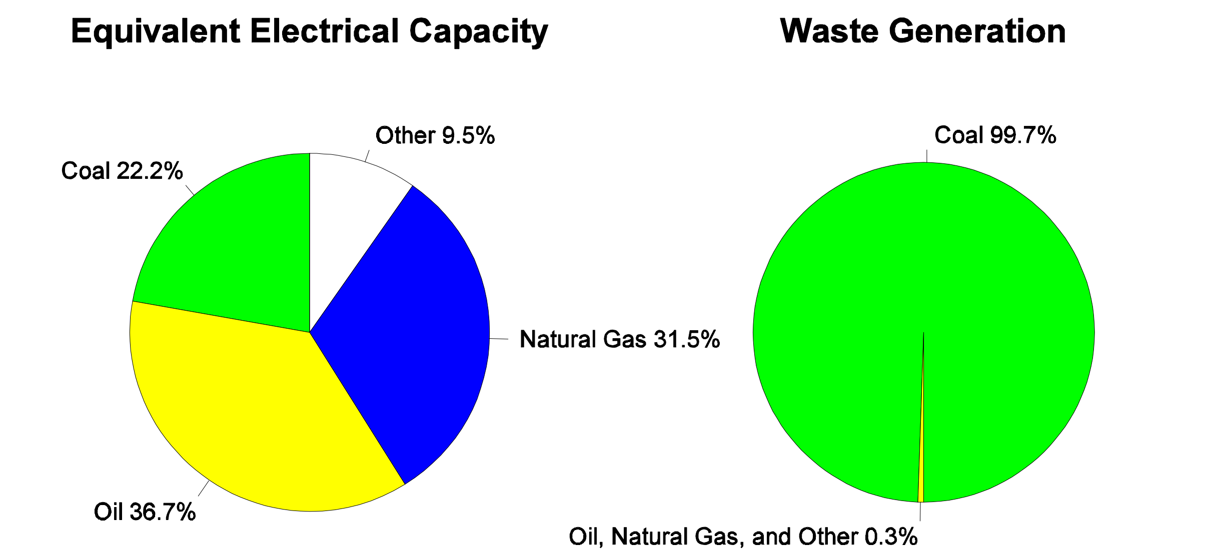
The Agency solicits comment on whether there are some minefill practices that are universally poor and warrant specific attention. For example, the Agency has found several situations where cement kiln dust placed in direct contact with the ground-water table has created problems. EPA specifically seeks comment on whether coal or other fossil fuel combustion wastes used as minefill and placed in direct contact with the water table would create other environmental concerns, and if that specific practice should be regulated. Last, with a few exceptions, use of these wastes as minefill is generally a recent practice and therefore long-term practices and environmental data cannot be assessed. The potential for risks associated with this practice may be of sufficient concern to consider whether some form of control under Subtitle C is appropriate, given the increasing trend for use of these materials as minefill. The Agency's focus is on potential risks that may be posed via the ground-water and surface pathways from use of these wastes as minefill. The Agency solicits additional information in the form of additional case studies of actual minefill situations, with the following types of information: minefill project design including areal extent, volumes, depth, environmental controls, mine spoils mixing ratio; characterization of combustion wastes that are involved; the background, pre-existing conditions in ground water at the mine location; and the depth to ground water at the mine location. The Agency is also interested in obtaining information on analytical modeling tools that can simulate fractured flow conditions and facilitate prediction of alkalinity consumption by acid mine drainage intrusion into the combustion wastes. The Agency will consider such comments and information in the formulation of the Regulatory Determination.

4.0 NON-UTILITY COAL COMBUSTION WASTES

Non-utility fossil fuel combustors do not produce and sell electricity as their primary industrial activity. Non-utility combustors are commercial, industrial, and institutional facilities that use fossil fuels in boilers to generate steam. Steam thus produced is used to generate electricity for captive use, to provide heat, or as a production process input. This chapter focuses on coal-fired non-utilities because of their much larger waste generation relative to other non-utilities. Coal combustion accounts for only 22 percent of non-utility fossil fuel generating capacity, but is responsible for the majority (greater than 99 percent) of non-utility fossil fuel combustion waste, as shown in Figure 4-1. Oil-fired boilers (covered in Chapter 6) and natural gas-fired boilers (covered in Chapter 7) account for larger shares of capacity, but generate very little waste. In addition to non-utility coal combustion waste (CCW), this chapter covers wastes from non-utilities combusting petroleum coke and coburning coal and other fuels.

Note that non-utilities, for purposes of this study, do not include independent power producers (sometimes called non-utilities in the electric power industry). Large-volume CCWs from independent power producers, when managed alone, were covered by the 1993 Regulatory Determination. Comanaged CCWs from independent power producers are covered in Chapter 3.

Figure 4-1. Non-Utility Fossil Fuel Combustion Sector by Fuel Type



Sources: Equivalent electrical generation capacity from EPA, 1990; waste generation based on EPA estimates.

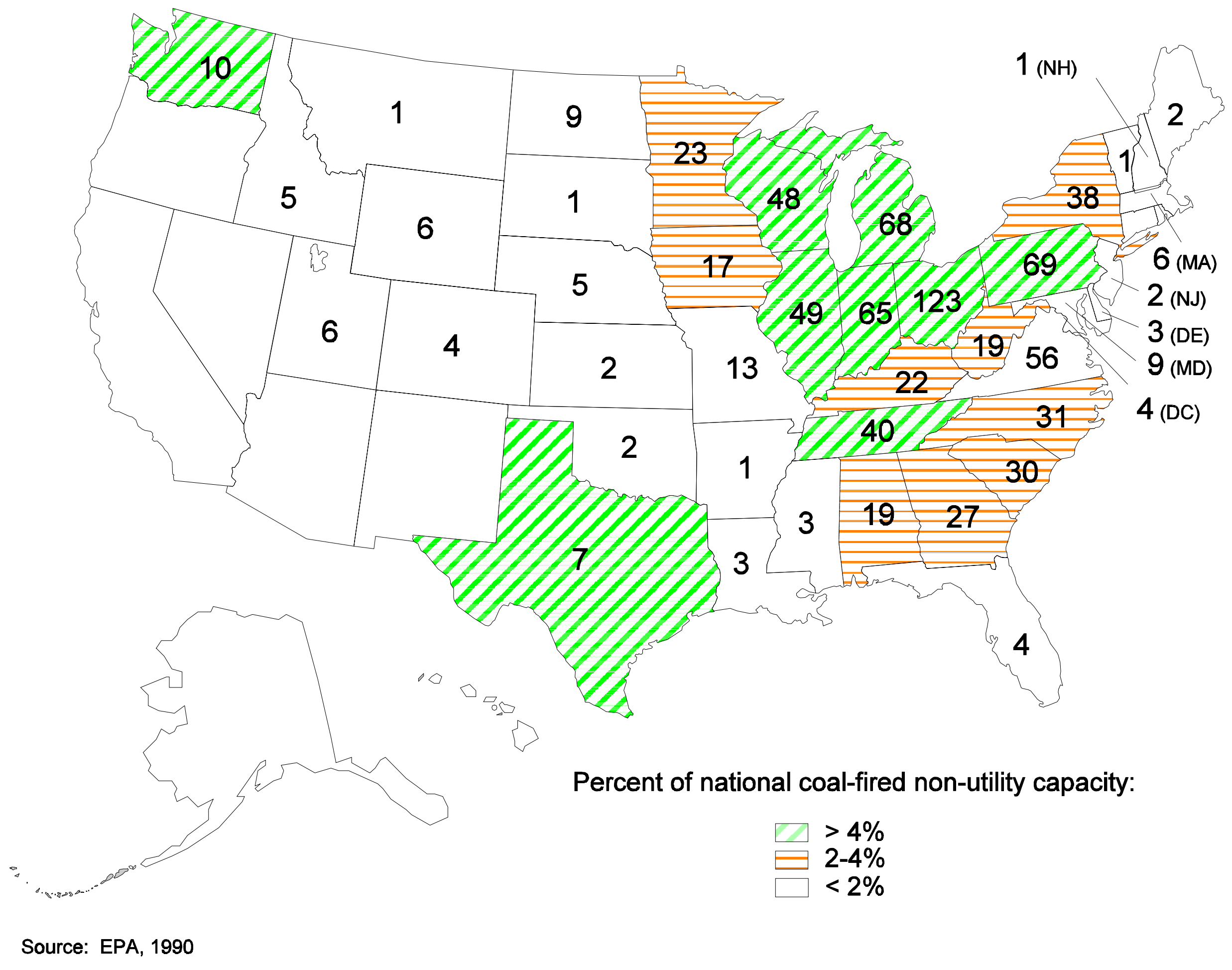
Sector Overview

The coal-fired non-utility sector is small relative to the coal-fired utility sector. In 1997, non-utilities consumed approximately 76 million tons of coal, compared to the 921 million tons consumed by utilities and independent power producers. Industrial facilities (as opposed to commercial or institutional combustors) account for the majority (92 percent) of non-utility coal usage (EIA, 1997e). The major industries accounting for a significant portion of coal-fired non-utility generating capacity include paper and allied products, chemicals and allied products, food and kindred products, primary metals, and transportation equipment (EPA, 1990). The 1990 U.S. EPA National Interim Emissions Inventory identifies 958 non-utility coal combustors in the United States operating nearly 2,300 individual boilers.

As discussed below, this figure is from a source that may underestimate the total number of non-utilities, but likely captures the majority of non-utility CCW generated. Note that cement kilns that burn fossil fuels are not included in the non-utility population covered by this study because these facilities are covered by the Report to Congress on Cement Kiln Dust.

As discussed in Chapter 2, non-utility coal combustion is expected to increase slowly through the year 2020. As shown in Figure 4-2, non-utility coal combustors are spread throughout the United States, with the largest numbers in the Northeast and Midwest. Most non-utility coal-fired electrical generation capacity is located in the same regions. Within states, facility settings vary from urban to rural. As discussed in Section 4.3, non-utilities practice both onsite and offsite waste management. Offsite waste management units are expected to be located near the generating facility in most cases. Therefore, the geographic distribution of combustion facilities presented in Figure 4-2 also approximates the universe of waste management locations.

Figure 4-2. Number of Non-Utility Coal Combustors by State



The 1990 U.S. EPA National Interim Emissions Inventory is a major source used in this study to characterize the non-utility coal combustion universe. This database includes information on major stationary point sources of air emissions. As such, it captures only the largest non-utility facilities; many small non-utility fossil fuel combustors are not included in the database. These small facilities, however, are expected to represent only a small percentage of the total capacity of the non-utility universe and are unlikely to generate significant quantities of waste.[1] Therefore, this source is representative of facilities that generate the majority of non-utility CCW. The database contains incomplete information from EPA Regions 9 and 10, thus underrepresenting facilities in some Western states.

4.1 WASTE GENERATION

Coal-fired non-utilities have the potential to generate the same four large-volume CCWs as utilities:

- **Fly ash.** Uncombusted material carried out of the boiler along with flue gases.

- **Bottom ash.** Uncombusted material that settles to the bottom of the boiler. Bottom ash does not melt and therefore remains in the form of unconsolidated ash.

- **Boiler slag.** Uncombusted material that settles to the bottom of the boiler. Slag forms when operating temperatures exceed ash fusion temperature, and remains in a molten state until it is drained from the boiler bottom.

- **Flue gas desulfurization (FGD) waste.** Waste produced during the process of removing sulfur oxide gases from flue gases (less likely to be generated at non-utilities than utilities, as discussed below).

As for utilities, the generation of these CCWs depends upon boiler technology (Section 4.1.1), air pollution control technology (Section 4.1.2), and fuel usage (Section 4.1.3). There are no comprehensive data on industry-wide generation of these non-utility CCWs. An annual ash generation rate, however, can be derived for coal-fired non-utilities using the data in the 1990 U.S. EPA National Interim Emission Inventory database (EPA, 1990). For these facilities, the estimated annual rate of CCW generation is approximately 5.8 million tons per year (EPA, 1997d). This estimate is significantly less than the quantity of CCWs generated by utilities due to the smaller total capacity of the non-utility sector and the factors discussed below (Sections 4.1.1 through 4.1.3). Because slow growth in non-utility consumption of coal is expected (see Chapter 2), dramatic increases in non-utility CCW generation are not expected.

Like utilities, non-utilities can generate low-volume combustion wastes as a result of supporting processes (see Section 4.1.4) that are ancillary to, but a necessary part of, the combustion and power generation processes. These low-volume wastes include the following:

- **Coal pile runoff.** Produced by precipitation falling on coal storage areas (less likely to be generated at non-utilities than utilities, as discussed below).

- **Coal mill rejects/pyrites.** Produced by onsite processing of coal prior to use (less likely to be generated at non-utilities than utilities, as discussed below).

- **Boiler blowdown.** Waste that is continuously or intermittently removed from boilers that recirculate water.

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[1] Small facilities are disproportionately populated by natural gas- and oil-fired units, which generate small or negligible quantities of solid waste. Small facilities burn less fuel, resulting in lower waste generation. Finally, small units are less likely to be fitted with air pollution control devices, decreasing the quantity of fly ash collected.

- **Cooling tower blowdown and sludge.** Wastes removed periodically from closed-loop cooling systems.

- **Water treatment sludge.** Wastes resulting from treatment of makeup water for the steam cycle or for non-contact cooling.

- **Regeneration waste streams.** Wastes resulting from periodic cleaning of ion exchange beds used to remove mineral salts from boiler makeup water.

- **Air heater and precipitator washwater.** Wastes resulting from the periodic cleaning of the fireside (i.e., the side exposed to hot combustion products) of heat exchanging surfaces.

- **Boiler chemical cleaning waste.** Wastes resulting from the periodic cleaning of the inside (waterside) of boiler tubes with chemical solutions.

- **Floor and yard drains and sumps.** Wastewaters collected by drains and sumps, including precipitation runoff, piping and equipment leakage, and washwater (may include wastes not associated with combustion processes).

- **Laboratory wastes.** Wastes generated in small quantities during laboratory analyses at the facility (may include wastes not associated with combustion processes).

- **Wastewater treatment sludge.** Sludge generated from the treatment in settling basins or other treatment facilities of liquid waste streams, including those above and others not associated with combustion processes.

Non-utilities would be expected to generate smaller quantities of these wastes, consistent with their smaller unit size (see Section 4.1.1). In some cases, non-utilities may generate insignificant quantities of some low-volume wastes (see Section 4.1.4).

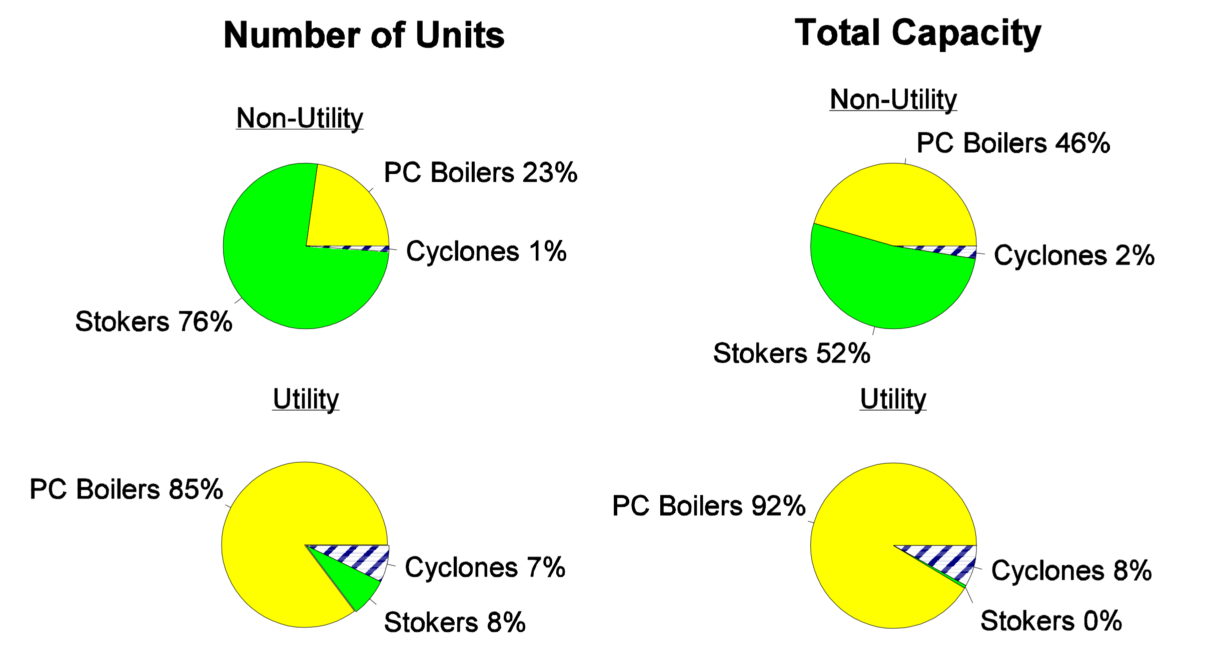
In addition to large-volume CCWs and low-volume wastes, non-utility combustors have the potential to generate a wide range of process wastes unrelated to the combustion of fossil fuels, consistent with the variety of industries represented by these facilities. These process wastes may be disposed along with combustion wastes. No comprehensive data exist on the quantity of low-volume wastes or non-combustion process wastes generated at non-utilities. For purposes of this study, however, the total quantity *generated* is less significant than the quantity *comanaged* with large-volume wastes. Section 4.3 presents the available data on the quantities of waste comanaged and the frequency of comanagement.

4.1.1 Boiler Technology

Coal-fired non-utilities use the same conventional combustion technologies as coal-fired utilities: pulverized coal (PC) boilers, stokers, and cyclones. All three conventional technologies involve combustion of coal in a boiler to heat water and produce steam. The steam may then be used to provide process heat or generate electricity. Note that when non-utilities generate electricity, they generally do so for onsite use rather than retail sale like the utilities and independent power producers covered in Chapter 3. The three conventional technologies differ in design, particularly in the type and the size of the coal particle to be burned, fuel delivery mechanisms, and the combustion conditions inside the boiler furnace. Chapter 3 provides a description of these technologies and their waste generation implications.

Figure 4-3 compares the technologies used in the non-utility sector to those in the utility sector. The figure shows that, while PC boilers predominate for utilities, both PC boilers and stokers are significant for non-utilities. Based on average capacity, non-utility units (14 megawatts average capacity) are smaller than utility units (256 megawatts average capacity). Examining the size distribution of individual boilers in Figure 4-4 confirms this observation. The majority of boilers in the non-utility industry are in the 0 to 50 megawatt equivalent range, while those in the utility industry range from 10 to 1,000 megawatts. This size difference is most obvious for PC boilers, however. Non-utility PC boilers are much smaller than those in the utility sector. Stokers in both populations are similar in size.

Figure 4-3. Comparison of Utility and Non-Utility Conventional Coal Combustion Technologies



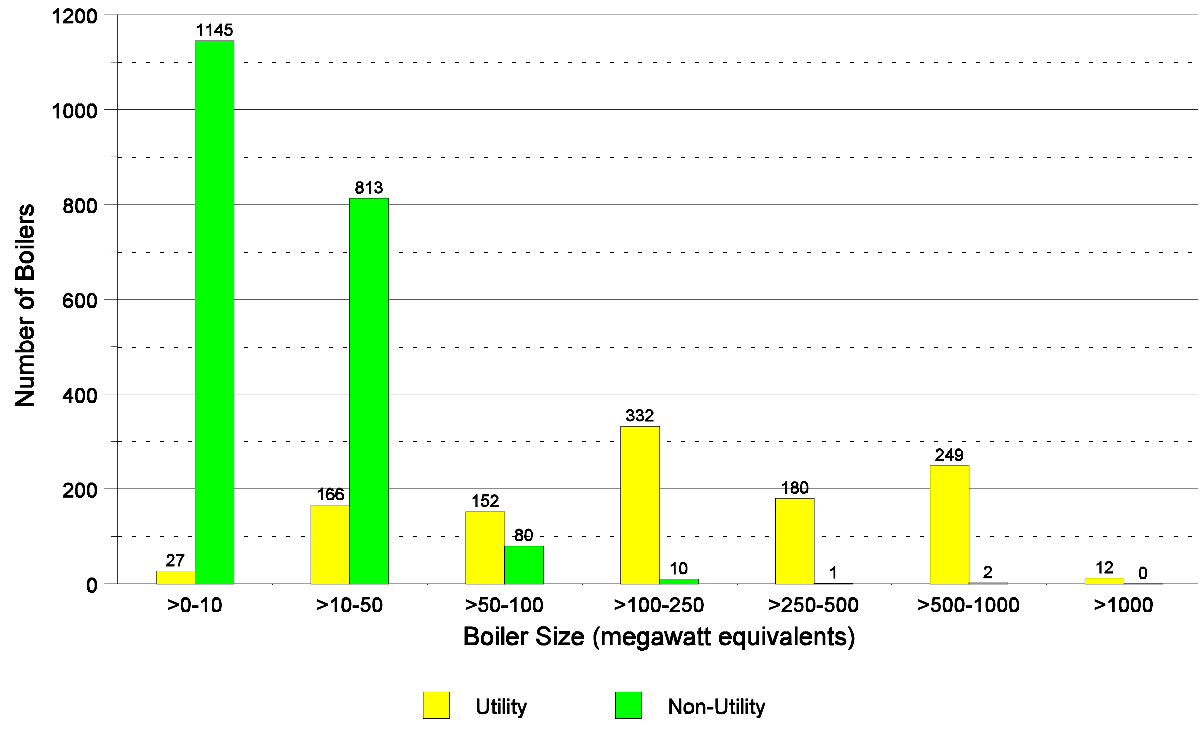
Sources: EEI, 1994; EPA, 1990

These differences in boiler technology have implications with respect to non-utility CCW generation. The generally smaller boiler size for non-utilities means lower fuel usage, and, in turn, less waste generation on a per-boiler basis. The greater proportion of stokers means greater waste generation per unit of energy generated, due to the lower efficiency of these units. The greater proportion of stokers also suggests a lesser percentage of the CCW generated will be in the form of fly ash.

4.1.2 Air Pollution Control Technologies

Air pollution control (APC) technologies used to meet the needs of coal combustion facilities may be categorized broadly as particulate controls and flue gas controls. The technologies of most relevance in the latter category are those for control of sulfur oxide emissions. As at utilities, the capture of non-utility fly ash is governed by the particulate control technology used. Fly ash leaving the boiler must be removed from the gas stream in which it is entrained or it will be released to the atmosphere. Generation of FGD waste results from the use of FGD technology. Chapter 3 describes both particulate control and desulfurization technologies.

Figure 4-4. Distribution of Coal-Fired Boilers by Capacity



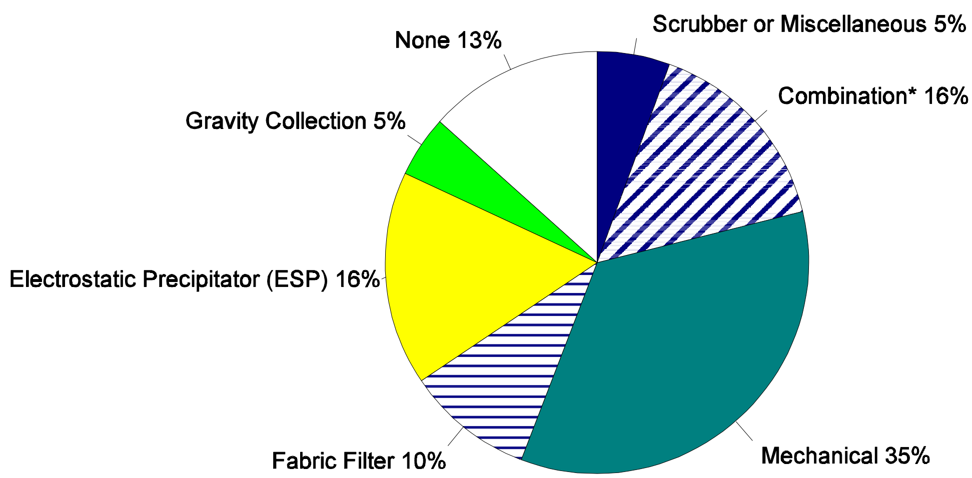
Note: Boilers not reporting size are not included.
Sources: EEI, 1994; EPA, 1990

Figure 4-5 shows data on particulate control devices employed at non-utilities. Due to their smaller size, non-utilities are less likely to be subject to particulate control regulations than utilities (see Section 4.5). As a result, a significant proportion of non-utilities does not use particulate controls or apply only low efficiency controls, such as gravity collection. This latter technique involves collecting fly ash that falls out of flue gas due to gravity at points where flow changes. Gravity collection has a low efficiency (less than 10 percent) compared to more complex particulate control devices. Units with gravity collection as their only control thus collect smaller quantities of fly ash. The proportion of units without particulate controls (or with low efficiency controls) leads to lower collection of fly ash in the non-utility sector.

Still, a large number of coal-fired non-utilities do employ high efficiency particulate control devices. These devices are most commonly mechanical collectors. This is because of the large proportion of stokers in the non-utility population. Stokers generate larger fly ash particles for which mechanical collection is efficient.

Of non-utility generating units that provided sulfur dioxide emissions information in the 1990 National Interim Emissions Inventory, only 4 percent reported using FGD technologies with the potential to generate FGD waste. A few units reported controlling sulfur dioxide emissions through combustion modifications or using particulate control technologies. The infrequent use of desulfurization technology for non-utilities may result from differences in regulatory requirements between large utility boilers and smaller non-utilities (see Section 4.5). Because of this, non-utilities as a group generate much less FGD waste than do utilities.

Figure 4-5. Particulate Control Technologies Used at Coal-Fired Non-Utilities



*Mechanical collector followed by fabric filter or ESP
Source: EPA, 1990

4.1.3 Fuel Usage

The quantity of ash and slag generated is affected by the ash content of the fuel. Ash content is, in part, determined by the rank of the coal: anthracite, bituminous, subbituminous, or lignite. These ranks reflect the degree of metamorphism of the coal and typically correspond to the geologic age of the coal deposit and to the heating value of the coal. Anthracite coal is the oldest rank and has the highest heating value, while lignite is the youngest and has the lowest heating value (Stultz and Kitto, 1992). Table 4-1 shows the usage of each rank by non-utilities in 1990, along with typical ash content. Non-utilities use the same four classes of coal as do utilities; however, a large percentage of non-utility use is bituminous coal.

Table 4-1. Fuel Usage by Coal-Fired Non-Utilities

Coal Class	Ash Content	Non-Utility Usage in 1990 (1,000 tons)	Percent of Total Usage
Anthracite	4–19%	609	1%
Bituminous	3–32%	56,762	89%
Subbituminous	3–16%	2,576	4%
Lignite	4–19%	3,998	6%
Total		**63,945**	**100%**
Sources: CIBO, 1997c; EPA, 1990			

In addition to coal rank, ash content depends on the specific coal producing region, mine, seam, and production method. The ash content of coal burned by non-utilities varies from state to state. On average, however, ash content of non-utility coal is less than that of utility coal, 7.58 percent compared to 9.22 percent in 1996 (EIA, 1998c).

The type of coal burned also affects the distribution of the ash and slag waste streams generated by combustion. For example, because softer lignite coals tend to have a lower ash fusion temperature, they tend to generate boiler slag rather than bottom ash.

Like utilities, coal-fired non-utilities may burn other non-coal fossil fuels, such as petroleum coke (see Section 5.1.3), or coburn coal with other fuels (see Section 3.1.3). No data are available on the extent of these practices at non-utilities. Their impacts on waste generation and characteristics, however, are expected to be similar to those discussed in Chapters 3 (for coburning) and 5 (for petroleum coke).

4.1.4 Supporting Processes

The generation of low-volume wastes primarily is associated with processes that support the combustion process or make use of the products of combustion. Some of the same supporting and enabling processes can accompany combustion at coal-fired non-utilities as at utilities, including the following:

- Coal storage
- Coal processing
- Steam generation
- Cooling
- Water treatment
- Cleaning and maintenance.

Chapter 3 describes these processes in detail. The paragraphs below describe potential differences in these processes at non-utilities with respect to waste generation. Little quantitative information is available on the quantities of low-volume wastes generated at non-utilities.

Coal Storage and Processing

Because of their small capacity, coal-fired non-utilities generally do not store large quantities of fuel onsite; therefore, they are less likely to generate significant coal pile runoff. Also, because of their small capacity, non-utilities are less likely to conduct onsite coal cleaning. The large proportion of stokers, which require less extensive feed processing than PC boilers, in the population means less need for coal processing at non-utilities. Therefore, many non-utilities may not generate coal mill rejects (including pyrites).

Steam Generation, Cooling, and Water Treatment

These processes generate low-volume wastes, including boiler blowdown, cooling tower blowdown, water treatment wastes, and regenerant wastes. The quantities of these wastes generated are related to the quantity of water used in the steam and cooling cycles, which in turn is related to combustion capacity. Because of their smaller capacity, non-utilities generally use less water in combustion-related processes, and, therefore, may generate smaller quantities of these wastes. In addition, some non-utilities use steam directly for heat in industrial processes rather than to generate electricity. In some cases, this practice may reduce the need for cooling, and in turn reduce the generation of wastes associated with the cooling cycle.

Cleaning and Maintenance

Cleaning processes intermittently generate low-volume wastes, including air heater and precipitator washwater and boiler chemical cleaning waste. Because of their small size, some non-utility combustors may require less frequent cleaning, using lower volumes of cleaning solution, than utilities. This can result in a lesser generation of cleaning wastes. For example, boiler fireside cleaning may take place so infrequently at a small non-utility combustor that the amount of cleaning waste generated over the life of the facility may be small. Eighteen coal-fired non-utilities reported the quantity of boiler fireside wash water and boiler waterside chemical cleaning rinse generated in response to a voluntary survey by the Council of Industrial Boiler Owners (CIBO). The plants reported a combined average annual volume of 35,941 gallons for both wastes (CIBO, 1997a).

4.2 WASTE CHARACTERISTICS

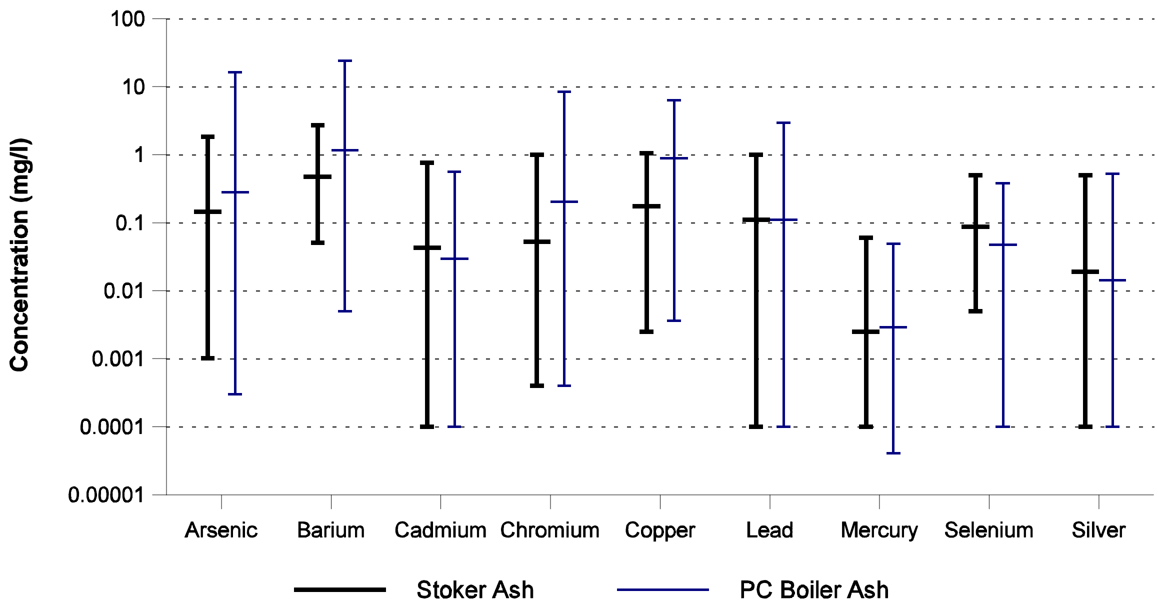
Analytical data to broadly characterize non-utility combustion wastes are not available. EPA, however, believes that non-utility CCW characteristics are similar to those of utility CCWs. The greater use of stoker technology in the non-utility sector does raise the possibility of differences in waste characteristics. Such differences might stem from differences in combustion conditions and fuel feed characteristics between stokers and the PC boilers used extensively by utilities. The available data, however, do not indicate that these differences are significant for the purpose of evaluating risk to human health and the environment.

CIBO provided a summary of leaching test results for fly ash and grate ash from stoker boilers (CIBO, 1998). CIBO obtained these data by voluntary survey of 33 facilities (non-utility and utility) with stoker boilers. Figure 4-6 compares these data with the leachate data for utility CCWs (from PC boilers) collected for the 1993 Regulatory Determination. For most of the constituents examined, mean concentrations in stoker ash are similar to or less than those in PC boiler ash. Also for most constituents, the range of concentrations observed for stoker ash are similar to or within the corresponding ranges for PC boiler ash. For selenium, the concentrations observed in stoker ash appear to be in the upper end of the range of concentrations observed in PC boiler ash. However, the maximum reported concentration for selenium in stoker ash appears to be an artifact of a high detection limit (0.5 milligrams per liter) in the analysis used for at least two samples. This detection limit drives the maximum concentration and inflates the mean concentration shown in Figure 4-6.

No data are available for organic constituents, dioxins, or radiation in non-utility CCWs. Based on the observed similarity of non-utility and utility CCWs with respect to metals, however, these other characteristics are not expected to be significantly different for non-utility CCWs. Data also are not available characterizing the smaller amounts of FGD waste expected to be generated by non-utilities. There is no reason, however, to expect non-utility FGD wastes to have significantly different characteristics than utility FGD wastes. Finally, the effects on waste characteristics of burning non-coal fossil fuels, such as petroleum coke, or coburning coal and other fuels, are expected to be similar to those discussed in Sections 3.2.3 and 5.2.

Based on the observed similarity of non-utility and utility CCWs with respect to constituents of concern, the risk assessment for non-utility CCWs relies on data for comanaged utility CCWs. Comanaged utility waste data were chosen, rather than data representing large-volume non-utility CCWs alone, because of the high rate of comanagement in the non-utility sector (see Section 4.3) and because the comanaged waste data are more extensive than the CIBO stoker ash data.

Figure 4-6. Comparison of Leachate Characteristics of Utility and Non-Utility Wastes



Sources: CIBO, 1998; supporting documentation to the 1993 Regulatory Determination

4.3 CURRENT MANAGEMENT PRACTICES

This section covers the management of wastes from the combustion of coal at non-utilities that use conventional (non-fluidized bed combustion) combustion technologies. The Agency evaluated two sources of data on this topic. The first is the CIBO non-utility survey (CIBO, 1997a). This was a voluntary survey of CIBO member companies and a select list of other companies known to operate non-utility boilers, conducted in support of this EPA effort. CIBO obtained responses from more than 50 coal-fired non-utilities. EPA believes this sample of facilities is representative of the non-utility population in terms of industries covered and boiler and air pollution control technologies used.

The second source is regulatory permit file information EPA collected on the generation and management of fossil fuel combustion (FFC) wastes from selected non-utilities in six states (Illinois, North Carolina, Virginia, New York, Pennsylvania, and Wisconsin). These six states were selected based on their large populations of non-utility boilers, both coal-fired and oil-fired.[2] The information available from this effort varies from state to state, depending on the information requirements of state regulations. For example, identification of waste management unit types was possible in five of the states, while extensive information on environmental controls was available in only three. Information from the search of state permit file information is used in this report to supplement the CIBO non-utility survey results.

[2] The selection criterion considered both coal-fired and oil-fired boilers in an effort to collect information for this section and Chapter 6 of this report; however, the state files contained little information regarding oil-fired boilers. Therefore, the state file information ultimately obtained covered coal-fired non-utilities only.

4.3.1 Unit Types and Location

Twenty-six coal-fired non-utility facilities provided information on waste management unit type in the CIBO non-utility survey. These 26 facilities appear to operate a total of 27 waste management units. This count assumes one management unit for each facility that reported a given management practice. For example, it assumes one surface impoundment for each facility that reported using a surface impoundment, when, in fact, the facility might have several impoundments. Thus, this analysis is based on a lower bound on the number of waste management units.

The available data indicate landfilling is the primary practice for non-utility CCWs, with few facilities operating surface impoundments. The 27 units identified in the CIBO non-utility survey include 25 landfills and only two surface impoundments. Of the 49 units identified in five of the states from which EPA obtained information,[3] 42 (or 86 percent) are landfills. The other seven units include four surface impoundments, a land application facility, and two units of unknown type. Non-utility waste management units also appear to include a large proportion of offsite units. The 25 landfills in the CIBO non-utility survey include eight commercial units (32 percent), which would be located offsite. The survey did not distinguish between onsite and offsite management for landfills owned by the respondent. Because the review of state permit file information was directed at facilities operating captive disposal units, the units identified in that effort all are onsite; however, other information collected during the review of permit files suggests that the majority of non-utility CCWs are managed offsite in at least three of the six states (Illinois, New York, and Pennsylvania). This is based on information from Pennsylvania's Residual Wastes Database and observations reported by officials in the other states.

A possible explanation for the predominance of landfills and the larger proportion of offsite units in the non-utility population is the power generating capacity of these facilities. As discussed in Chapter 3, the smaller coal-fired utilities tend to dispose offsite in landfills, most likely because of economies of scale and available space. If similar trends hold for non-utilities, one would expect a larger proportion of landfills and offsite units for these small facilities as well.

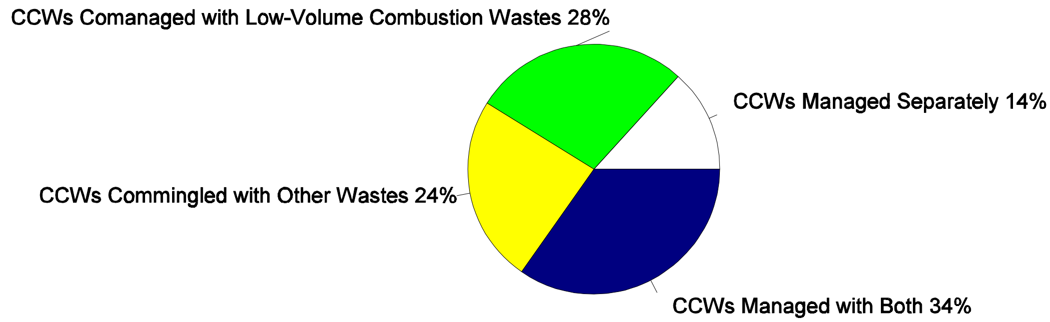
4.3.2 Types of Waste Managed

As at utilities, large-volume CCWs at non-utilities frequently are combined for management. Sixty-one percent (31 of 51) of coal-fired non-utilities providing information in the CIBO non-utility survey manage bottom ash and fly ash in the same unit. Just under half (4 of 9) of the facilities generating FGD waste manage this waste in the same unit as fly ash.

As discussed in Section 4.1, non-utilities have the potential to manage large-volume CCWs with a great variety of other wastes because they may generate both low-volume combustion wastes and wastes from other processes. Figure 4-7 describes the combined management of other wastes with non-utility CCW, based on the CIBO non-utility survey. As shown in Figure 4-7, commingling of large-volume CCWs and other wastes at non-utilities appears to be as common as at utilities (see Section 3.3). The state permit file information generally supports this observation. For onsite landfills in two of the three states for which information on combined management is available, 90 percent or more of the units combine FFC wastes and other wastes (9 of 10 landfills in North Carolina and 17 of 18 landfills in Wisconsin). On the other hand, in Pennsylvania, most non-utility CCW that is managed onsite is managed separately in monofills. For offsite landfills, quantitative data are not available from the state

[3] Information on management unit types was not available for the sixth state from which EPA collected information.

Figure 4-7. Combined Management of CCWs with Other Wastes at Non-Utilities



Note: Data shown are the 29 facilities that provided information about waste combinations managed.
Source: CIBO, 1997a

files concerning the prevalence of comanagement; however, offsite landfills are likely to include commercial units that accept a variety of wastes in addition to CCWs.

Table 4-2 details the specific types of wastes reported in the CIBO non-utility survey. Low-volume combustion wastes comanaged include the same types reported for utilities, although coal mill rejects (pyrites) in particular are comanaged less frequently at non-utilities. This is likely because, as discussed in Section 4.1, coal mill rejects are less likely to be generated at non-utilities. The table also shows a number of types of non-combustion wastes. Wastes identified in the state permit file information include an even greater variety of non-combustion wastes: construction debris, paper and wood mill waste, bark, lime, wood ash, spent alum mud, pulp fiber, incinerator ash, dimethyl-terephthalate, terephthalate acid, wastewater treatment sludge, aluminum sludge, filter cake, reactor bottoms, spodumene ore residue, decrepitation kiln solids, asbestos, metallurgical process residues, filter pads, plastics, pipe insulation, scrap metal, fibrets, crushed coal, masonry waste, paper products, sand, oily soil, and sulfite liquor.

4.3.3 Environmental Controls

Information was available on environmental controls including liners, leachate collection, ground-water monitoring, and runoff controls from the state permit files in three of the six states studied (North Carolina, Virginia, and Wisconsin). In addition, the CIBO non-utility survey collected information on the use of liners and issuance of regulatory permits. Table 4-3 summarizes this information.

The state permit file data suggest that environmental controls are common at non-utility landfills; however, the state permit file sample may be biased in this regard. Because they were identified through state permit files, these units are subject to some form of regulatory oversight (e.g., permit review, inspections, monitoring). This regulatory oversight may have resulted in the imposition of environmental controls at these units. The liner data from the CIBO non-utility survey, which show a much lower percentage of landfills with controls, support the hypothesis that the state permit file data reflect a sample bias toward environmental controls. Based on this, the prevalence of environmental controls at non-utility landfills may be less than that at utilities.

Table 4-2. Types of Wastes Comanaged with Non-Utility CCWs

Waste Type	Number of Non-Utilities	Percent of Plants Reporting (25 facilities)
Low-Volume Combustion Wastes		
Boiler Blowdown	8	32%
Demineralizer Regenerant/Rinses	6	24%
Coal Mill Rejects/Pyrites	6	24%
Water Treatment Wastes	6	24%
Boiler Cleaning Chemical Waste	5	20%
Air Preheater/Precipitator Wash Waste	4	16%
Cooling Tower Blowdown	3	12%
Coal Storage Pile Runoff	2	8%
Other Wastes*		
Wastewater Treatment Sludges/Residuals	8	32%
General Site Runoff	7	28%
Floor Drains/Sumps	6	24%
Laboratory Wastes	5	20%
Miscellaneous Plant Wastes	5	20%
Domestic/Municipal Wastes	3	12%
Contaminated/Dredged Soils	2	8%
Other Unspecified Wastes	5	20%

* Wastes not clearly related to combustion processes were categorized as other wastes.
Source: CIBO, 1997a

Table 4-3. Environmental Controls at Non-Utility CCW Landfills

Environmental Control	Number of Units Reporting Data on Each Control[a]	Percent with Control[a]	Data Source
Liner	19	16%	CIBO non-utility survey
	27	52%	State permit files
Leachate Collection	30	67%	State permit files
Runoff Control	6	100%	State permit files
Ground-Water Monitoring	34	94%	State permit files
Regulatory Permit	23[b]	65%[b]	CIBO non-utility survey

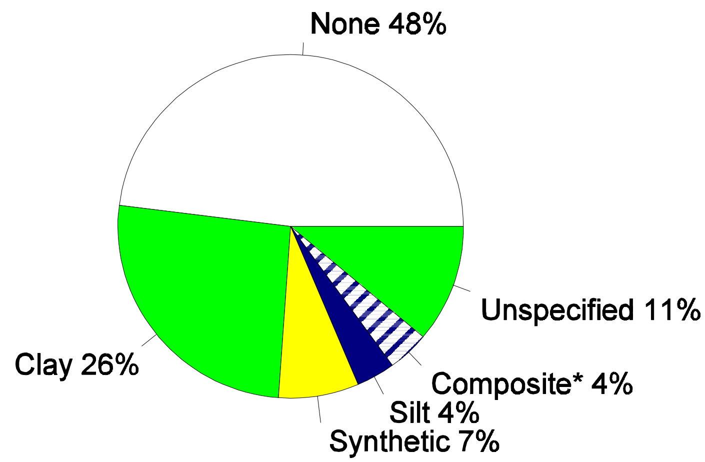
[a] The number of facilities reporting data on the presence or absence of each control type was different for each control type. For example, it was possible to determine the presence or absence of leachate collection systems at 30 facilities. Twenty of these 30 (67 percent) had leachate collection systems. The other 10 (33 percent) did not. Information on leachate collection systems was not available for units other than these 30.

[b] Data presented is number of non-utility plants, not number of management units. Unit-specific information was not available. Three of the facilities counted as unpermitted indicated that permits are required, but have not yet been issued. Once these permits have been issued, the percentage of permitted non-utility facilities would increase to 78 percent.

Liners

As discussed above, the CIBO data suggest a much lower percentage of landfills are lined than the state permit file information may indicate. It is unclear which sample is more representative, although the state permit file units are not geographically representative and are probably biased toward having liners. Figure 4-8 shows the types of liners reported in the state permit file information. Only limited data exist for non-utility surface impoundments. The two impoundments in the CIBO non-utility survey are unlined.

Figure 4-8. Types of Liners at Non-Utility CCW Landfills



*Composite liners consist of clay and synthetic layers.
Source: State permit files

4.3.4 Beneficial Uses

Current statistics are not available on the quantities of non-utility CCWs that are utilized; however, available data indicate that beneficial use of these wastes does indeed occur. The small sample of facilities responding to the CIBO non-utility survey (CIBO, 1997a) provided information on whether they utilize some of their CCW. Table 4-4 summarizes these responses. Overall, 56 percent of respondents described one or more beneficial uses. The uses reported are the same as those described for utility CCWs, with cement and concrete and construction fill uses being reported most commonly. These results are consistent with the statistics showing these uses to be the most common for utility CCW.

Based on these results and because of the similarities between utility and non-utility CCWs, EPA believes that nearly all of the beneficial uses described for utilities also are applicable to non-utility wastes. In some cases, economic barriers to the commercialization of these uses for non-utility CCWs may exist because of the smaller volumes of waste generated. Individual non-utility generators may not be able to competitively market their byproducts for uses (such as construction fill) that require large volumes of CCW. The extent of such barriers, as well as techniques for overcoming them, require further investigation.

Table 4-4. Non-Utility FFC Waste Beneficial Uses

Beneficial Use	Number of Facilities Reporting	Percent
Do Not Utilize	22	44%
One or More Beneficial Use*	28	56%
Cement/Concrete	18	36%
Flowable Fill	6	12%
Structural Fill	14	28%
Road Base/Subbase	13	26%
Miinefill	8	16%
Agricultural Use	7	14%
Waste Stabilization	5	10%
Snow and Ice Control	3	6%
Blasting Grit/Roofing Granules	1	2%
Mineral Filler	1	2%
Total	**50**	**100%**

* Total shown is less than the sum of individual uses because a facility may employ more than one beneficial use.
Note: Data shown are for the 50 (of 51) facilities that provided beneficial use information.
Source: CIBO, 1997a

4.4 POTENTIAL AND DOCUMENTED DANGERS TO HUMAN HEALTH AND THE ENVIRONMENT

4.4.1 Potential Ground-Water Risks to Human Health

Section 3.4 provides a discussion of the methodology employed by EPA in assessing risks from coal-fired utility comanaged wastes. EPA followed a similar approach for wastes from the non-utility sector, with several important differences. First, EPA initially obtained very few data on the characteristics of wastes generated in non-utility boilers. To overcome this data gap, EPA used the waste characterization data developed for the utility comanaged waste sector to represent wastes from non-utilities. As non-utility data were developed and provided by industry (CIBO, 1998), EPA compared utility and non-utility waste characteristics as a function of fuel, boiler type, and boiler size to corroborate the initial assumption that the wastes from the sectors are similar (see Section 4.3). Second, EPA found the primary differences between the sectors, from a risk assessment standpoint, to be in waste management practices and waste unit sizes. Non-utility boiler operators were found to generate smaller quantities of wastes overall, and to manage these wastes either in small onsite landfills or large onsite or offsite units containing primarily other non-FFC wastes. EPA found the proportion of FFC wastes in most mixed waste disposal units to be small, and, therefore, judged the risks from such units attributable to FFC wastes to be similarly small. EPA, therefore, focused its examination of ground-water pathway risks on small onsite landfills. Finally, EPA found that non-utility boilers reflect a geographic distribution distinct from the larger utilities, and so modified its modeling scenarios accordingly.

Note that EPA did not model risks from minefilling of non-utility FFC wastes. EPA believes minefill practices to be the same for utility and non-utility operators. See Section 3.4.5 for an overview of EPA concerns and data limitations for minefills.

Non-Utility Ground-Water Risk Findings

Table 4-5 summarizes selected results from the deterministic and probabilistic analyses of risk from non-utility coal combustion wastes for the adult receptor. Overall, EPA found that the risks associated with all modeled constituents of concern, except for arsenic, fell below a hazard quotient (HQ) of 1 or lifetime cancer risk of 1×10^{-6}. Potential risks associated with arsenic in the high-end deterministic scenario exceeded 1×10^{-4}.

Table 4-5. Comparison of Deterministic and Monte Carlo Risk Model Results for Non-Utility Coal Combustion Waste Ground-Water Pathway Scenario

Scenario	Constituent[b]	Deterministic Risk, Central Tendency	Deterministic Risk, High-End	Corresponding Monte Carlo Percentile	Monte Carlo 95th Percentile
NM[a]	Arsenic	1.4×10^{-8}	1.8×10^{-4}	99	6.5×10^{-6}
	Barium	HQ <1	HQ = 0.2	99	HQ = 0.002

[a]NM = non-utility onsite monofill (i.e., managing CCWs and low-volume combustion wastes, but not other non-combustion industrial wastes).
[b]Constituents are limited to those for which estimated risks exceeded target values in the April 1998 Draft Final Report. Revised nickel screening results were HQ <1 so modeling results are not reproduced here. All other metals modeled yielded an HQ <1
Note: Results shown are those from the October 10, 1998, Sensitivity Analysis.

Comparison of the deterministic and Monte Carlo results reveals that the deterministic results exceed the 95th percentile Monte Carlo results. Specifically, 99 percent of the 2,000 Monte Carlo simulation combinations of parameter values exceed the deterministic high-end results for arsenic and for barium. Even at the 95th percentile level, the risks predicted by the Monte Carlo simulations were almost two orders of magnitude below the corresponding risks estimated for the high-end scenario.

In essence, using coal-fired utility comanaged waste characteristics data for the non-utility analysis, EPA found cancer risk from arsenic from onsite landfills to be similar to those found for comanaged wastes, at the 1×10^{-4} level. EPA also considered the time at which risks were predicted to result from the release of constituents of concern. EPA found that the concentration of arsenic in ground water at the receptor well would not reach the health-based levels (HBL) for arsenic (i.e., achieve a risk level of 1×10^{-6}) for more than 1,400 years.

Table 4-6 summarizes the estimated risks to adult and child receptors for the high-end deterministic scenario for non-utility CCWs. Overall, the results show that risks to the two child types and adult were similar.

Table 4-6. Comparison of Adult and Child Risk Model Results for Non-Utility Coal Combustion Waste – Ground-Water Pathway Scenario

Scenario	Constituent[b]	High-End Deterministic Risk		
		Adult	Young Child	Child
NM[a]	Arsenic	1.8×10^{-4}	2.3×10^{-4}	1.6×10^{-4}
	Barium	HQ = 0.2	HQ = 0.3	HQ = 0.2

[a]NM = Non-utility on-site monofill (i.e., managing CCWs and low-volume combustion wastes, but not other non-combustion industrial wastes).
[b]All other metals modeled yielded HQ <1
Note: Results shown are from the October 10, 1998, Sensitivity Analysis

4.4.2 Potential Above-Ground Multi-Pathway Risk to Human Health and the Environment

Human Health Risk

Similar to the results discussed in Section 3.4.2, no plausible non-ground-water risks were found for the non-utility wastes except in the event of possible use in agricultural applications, where risks would be similar to those noted for the utility wastes (in excess of 10^{-5}).

Ecological Risk

No ecological risks were found for this category of ash in that no disposal in large surface impoundments was noted.

4.4.3 Documented Damages to Human Health and the Environment

Summary of Findings

EPA collected information on the generation and management of combustion residues at non-utilities from six states (Illinois, New York, North Carolina, Pennsylvania, Virginia, and Wisconsin). Detailed, facility-specific information for about 50 sites was collected from conversations with State personnel and the review of facility-specific files at state offices. Based on this review, EPA concluded that none of these sites meet the "test of proof" for damage cases. Although releases of waste have been documented and ground-water monitoring results show exceedences of standards in some cases, documentation was not available which would satisfy the EPA tests of proof for damage cases.

EPA also reviewed four Superfund Records of Decision (ROD) involving non-utility CCWs (codisposed with other wastes). In one of these decisions (Wheeler Pit, Wisconsin, ROD/R05-90/130), no principal threat warranting treatment has been identified. In a second decision (U.S. DOE Feed Materials Production Center), FFC wastes were found not to contribute to contamination.

In the remaining two cases, non-combustion wastes are codisposed with CCWs and the source of the ash (utility or non-utility) is unspecified. In one case, the Lemberger landfill (Wisconsin, ROD/R05-91/186), the source material does not implicate, or rule out, contributing influences from CCWs. In the second case, Salem Acres (Massachusetts, ROD/ROI-93/078), an area used as a fly ash waste pile is identified as a potential source of risk.

Based on information available and in consideration of EPA's "tests of proof," EPA identified the cases in Table 4-7 as potential damage cases.

Cases Meeting Test of Proof

The Salem Acres (Massachusetts) National Priority List site comprises unlined sludge lagoons containing tannery wastes (typical components include chromium and greases), contaminated soil areas, a landfill, a debris pile, and a fly ash pile. Wastes were disposed at the site from the mid 1940s to 1969; the source of the ash (utility or non-utility) was not described in the source documents. The volume of fly ash is estimated to be 9,600 cubic yards; the volume of lagoon sludge is estimated to be 21,000 cubic yards. Therefore, the ash represents a significant percentage of the overall waste volume present. Ground-water monitoring showed arsenic to be present below its maximum contaminant limit. The ROD concluded that several areas of the site, including the fly ash pile, pose health risks exceeding risk management criteria. Ground-water risks from antimony and manganese also were identified.

Table 4-7. Potential Damage Cases

Damage Case	Wastes Present	Event	Test of Proof	Comment
Salem Acres (MA)	Large volume; many other wastes present including MSW and ISW	PAHs, VOCs, PCBs, and metals, including As and Cr, in soils, surface waters, and ground water	Administrative (on NPL)	Contribution of FFC wastes to damage not separable from other wastes. Remedial measures include excavation, treatment, and removal of sludges and soils; proposed fixation with fly ash; Subtitle C capping if performance criteria are not met
Lemberger Landfill, Inc. (WI)	Comanaged wastes; many other materials including MSW, with adjacent site receiving ISW	Elevated concentrations of As, Cr, and Pb onsite, plus VOCs, PCBs VOCs in private wells initiated action	Administrative (on NPL)	>$20 million cleanup Contribution of FFC wastes to damage not separable from other wastes

An old gravel pit, the Lemberger Landfill (Wisconsin) was used for waste disposal from 1940 to about 1980. Wastes disposed included general refuse, power plant fly ash (1969 to 1977) and bottom ash (1969 to 1976), and municipal solid waste. Other industrial wastes also were disposed at a nearby site. Environmental effects and damages included the seepage of landfill leachate into adjacent property, presence of volatile organic compounds in drinking water wells, the presence of organic compounds in surface water, and potential effects from direct soil or waste contact. Inorganic constituents detected in the ground water include barium, cadmium, and chromium. The source of contamination was identified as the landfilled waste, although specific wastes were not identified in the ROD as contributing or not contributing to the ground-water contamination.

Evaluation of the sites is complicated by three factors: disposal ceased at least 10 years ago, non-combustion wastes are mixed with CCWs at each of the sites, and the information does not specify if CCWs result from utility or non-utility operations. These two cases, however, meet EPA's tests of proof as damage cases for purposes of this study.

4.5 EXISTING REGULATORY CONTROLS

EPA's objective in this analysis was to identify and evaluate the existing regulatory controls that pertain to the management of non-utility CCWs. The regulatory analysis is directed toward addressing the question of whether existing regulations adequately protect human health and the environment. The analysis also is helpful in understanding waste generation and current management practices.

The sections below discuss regulations addressing air pollution, water pollution, and solid and hazardous waste, respectively. Air regulations are relevant primarily because of their effect on waste generation. Water regulations have an influence both on waste generation and management and, in particular, address the impact of CCWs on surface waters. Solid and hazardous waste regulations are of the greatest interest because they directly govern waste management practices.

The sections below describe federal regulations in each of these areas. In many cases, the implementation of these federal programs is carried out by the states. Therefore, where appropriate, aspects of state implementation also are discussed. Because the nuances of state implementation are of particular importance with respect to solid waste regulation, state solid waste programs are discussed in detail. Where appropriate, state controls on two of the CCW beneficial uses of concern to EPA—minefilling and soil amendment—are described.

4.5.1 Regulations Addressing Air Pollution

The federal Clean Air Act (CAA) is intended to protect and enhance the quality of the nation's air resources. The CAA requirements most relevant to non-utilities include the following:

- National Ambient Air Quality Standards (NAAQS) for particulate matter (PM)
- NAAQS for sulfur dioxide
- NAAQS for ozone
- National Emissions Standards for Hazardous Air Pollutants (NESHAP).

Title IV acid rain provisions, the fifth set of requirements that affect fossil fuel combustors as a group, currently apply only to the largest coal-fired *utility* generating units, and, therefore, are not relevant for non-utility units. Historically, CAA requirements have been a significant factor affecting the generation and collection of certain non-utility CCWs (specifically fly ash and FGD waste). Recent and forthcoming changes in these requirements also may impact waste generation or characteristics, as discussed below.

NAAQS for Particulate Matter

The NAAQS for PM establish maximum concentrations of PM with diameter less than or equal to 10 micrometers (PM10) in the ambient air. These standards are among the factors motivating the use of particulate control technologies at FFC facilities. EPA recently proposed to lower the size criterion to 2.5 micrometers, which may affect the volume of fly ash collected and selection of control technology; however, final standards will not be issued for at least 5 years, so the impacts of the new standard are difficult to predict at this time.

The NAAQS for PM are implemented through New Source Performance Standards and State Implementation Plans.

New Source Performance Standards (NSPS). The NSPS subject newly constructed or modified units to specific PM emissions limits. These limits may be met by changing fuel types, modifying combustion conditions, or installing control devices. The applicability of the NSPS and the specific limits imposed vary with the age and size of the combustion unit, with older and smaller units less likely to be subject to the NSPS. Specifically, the regulation of non-utilities can be considered in the following three categories (one of the four categories discussed for coal-fired utilities in Chapter 3—facilities subject to Subpart Da—applies specifically to utilities; therefore, it is not relevant to non-utilities):

- 40 CFR 60 Subpart D governs the standards of performance for new fossil fuel-fired steam generators that were constructed or underwent major modification after August 17, 1971. Subpart D affects only units that are capable of burning fossil fuels at greater than 73 megawatts (MW) of heat input rate.

- Subpart Db affects coal-fired units with the capacity to fire fuel at greater than 29 MW of heat input rate that commenced construction or modification after June 19, 1984.

- Subpart Dc governs coal-fired units constructed or modified after June 9, 1989, with capacity to fire fuel at less than 29 MW but greater than 8.7 MW of heat input rate.

The NSPS requirements discussed above apply to all fossil fuel steam generating units, utility or non-utility. Non-utilities, however, tend to have smaller capacities than utilities, and, therefore, are more likely captured by those NSPS requirements that apply to smaller capacity units (i.e., Subparts Db and Dc). Under the NSPS regulations, facilities that were in operation before the dates stated in each of the subparts are considered "grandfathered" and would not be subject to the newer standards unless they underwent a major modification.

State Implementation Plans (SIPs). The performance standards above can be enforced by a Federal, State, or local regulatory agency. There are additional CAA regulations that could require a coal-fired unit to install a particulate removal device notwithstanding the grandfather clause in Subparts D, Db and Dc. SIPs may impose, on a state-by-state basis, PM controls of varying stringency on specific sources or categories of sources, including coal-fired non-utilities. Such controls are required under Title I of the CAA if a particular area is in nonattainment for the NAAQS for a criteria pollutant such as PM. For this reason, SIP controls will generally be more stringent in such nonattainment areas. In attainment areas, the prevention of significant deterioration (PSD) program requires new sources to apply Best Available Control Technology (BACT), which must be at least as stringent as NSPS.

NAAQS for Sulfur Dioxide

Like the NAAQS for PM, the NAAQS for sulfur dioxide establish a maximum concentration of sulfur dioxide in the ambient air. The NAAQS for sulfur dioxide are implemented through NSPS and SIPs. The functioning and applicability of the sulfur dioxide NSPS requirements are similar to those for PM, although there is less variation based on age and size.

Each of the three categories of coal-fired non-utilities regulated under Subparts D, Db, and Dc is subject to the same requirement: sulfur dioxide emissions must be less than 520 nanograms per joule (ng/J) of heat input. Facilities with greater than 22 MW of heat input capacity generally also must achieve a 10-percent reduction in their sulfur dioxide emissions, based on the potential concentration in fuel. An additional category of coal-fired facilities, those constructed or modified after June 9, 1989, and between 2.9 and 8.7 MW of heat input capacity, also must meet the 520 ng/J standard, but may do so based on certification from the fuel supplier that the sulfur content of the fuel is low enough to meet the standards.

In addition to NSPS, states may impose controls through their SIPs to meet the sulfur dioxide NAAQS. These controls may vary in stringency depending on attainment status and may be placed on specific sources or categories of sources, including coal-fired non-utilities.

In spite of the similarities in NAAQS programs for sulfur dioxide for utilities and non-utilities, the prevalence of FGD technologies among non-utilities is less than that among utilities (see Section 4.1). This may be because Title IV requirements currently do not apply to non-utilities, because of the lack of percent reduction requirements on these smaller facilities, because of differences in fuel characteristics, and/or because of differences in SIP requirements for non-utilities.

NAAQS for Ozone

The NAAQS for ozone establish a maximum concentration of ozone in the ambient air. EPA recently lowered this concentration from 0.12 parts per million (ppm) to 0.08 ppm. The new standard allows four exceedences of the maximum in a region over a 3-year period. EPA expects states will meet the new standard by amending their SIPs to limit nitrogen oxide emissions at utilities. Therefore, the recent changes are not expected to affect non-utilities (and, in turn, non-utility waste generation) significantly.

NESHAP

Under the NESHAP, EPA is required to establish technology-based standards for 189 hazardous air pollutants (HAPs). These standards are to be set on an industrial category basis and will apply to facilities that emit greater than 10 tons/year of any one HAP or greater than 25 tons/year of any combination of HAPs.

EPA has not specifically studied HAP emissions from non-utility coal combustors. Because NESHAP will be set on an industrial category basis, when promulgated, the impact of these regulations on waste generation and characteristics may vary depending on the industrial sector of the non-utility combustor.

4.5.2 Regulations Addressing Water Pollution

Under the federal Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) controls discharges to waters of the United States. As discussed below, the controls required under NPDES affect the collection and management of CCWs. In states authorized by EPA, these controls are implemented through state programs (often termed State Pollutant Discharge Elimination Systems, or SPDES). Because state programs must be at least as stringent as the federal program, the discussion here focuses on federal requirements as a lowest common denominator. NPDES requirements apply differently to two categories of discharges: process wastewaters and stormwater runoff.

NPDES Requirements for Process Wastewaters

Non-utility coal combustors face NPDES requirements for process wastewaters that are specific to their industrial sectors. In most cases, under these requirements each discharge requires an individual NPDES permit with numeric limitations based on Best Practicable Control Technology Currently Available (BPT), Best Available Technology Economically Achievable (BAT), or New Source Performance Standards (NSPS). Facilities that discharge to publicly owned treatment works (POTWs) rather than directly to surface waters face Pretreatment Standards for Existing Sources (PSES) similar to BAT or BPT or Pretreatment Standards for New Sources (PSNS) similar to NSPS.

As discussed in Section 4.3, non-utility CCWs are rarely managed wet (although they may be conditioned with liquids during management for dust control). Therefore, the NPDES process wastewater requirements generally are not relevant to management of these wastes. In those cases in which these wastes are managed wet, the most relevant requirements are total suspended solids (TSS) limits. The specific NPDES effluent standards applicable to a non-utility depend on the facility’s industrial category. Effluent standards expected to apply to large numbers of non-utility fossil fuel combustors include those for the following industry categories:

- Pulp, paper, and paperboard (40 CFR Part 430)
- Organic chemicals, plastics, and synthetic fibers (40 CFR Part 414)
- Inorganic chemicals manufacturing (40 CFR Part 415)
- Textile mills (40 CFR Part 410)
- Timber products processing (40 CFR Part 429)

- Iron and steel manufacturing (40 CFR Part 420)
- Sugar processing (40 CFR Part 409)
- Grain mills (40 CFR Part 406).

The standards for these categories include TSS limits, and these limits are applicable to nearly all of the industrial subcategories covered under each category. Some subcategories are subject to zero discharge requirements. Based on the SIC codes reported by non-utilities in the 1990 U.S. EPA National Emissions Inventory database, these industrial category requirements are expected to cover roughly 20 percent of non-utility fossil fuel combustors. A number of other facilities are scattered through other industrial categories, many of which are also subject to TSS limits. Some facilities (such as institutional fossil fuel combustors) may not be subject to the specific standards of any industrial category. In these cases, the specific effluent limitations would be determined on a case-by-case basis as part of the non-utility's individual NPDES permit.

In addition, the steam electric category NPDES requirements applicable to utilities also may be incorporated in individual permits at non-utilities to supplement their industrial category requirements. Application of steam electric requirements to relevant waste streams at non-utility fossil fuel combustors is left to the best professional judgement of the individual permit writer (EPA, 1996). The steam electric category NPDES requirements place TSS limits directly on fly ash handling and bottom ash handling waters. In addition, the NSPS for the steam electric category include a zero discharge requirement for fly ash handling water.

In those cases in which non-utility CCWs are managed wet, the TSS and zero discharge requirements discussed above are relevant as follows. Facilities may have to settle or otherwise remove a certain amount of waste solids from the handling water to meet the TSS limits prior to discharge. Zero discharge requirements effectively eliminate the release of waste solids to surface water; thus, the requirements control the direct release of fly ash, bottom ash, and any treatment solids to surface waters.

NPDES Requirements for Stormwater

NPDES stormwater requirements apply to stormwater runoff from FFC facilities. Stormwater runoff may include runoff from operating areas, ash handling areas, and waste management units. Like the process wastewater requirements, stormwater requirements have been established on an industrial sector basis. The NPDES stormwater requirements, however, are additive across industrial sectors. Therefore, steam electric stormwater requirements apply to non-utilities just as they apply to utilities. A chemical manufacturer, for example, operating a fossil fuel-fired boiler must meet both chemical manufacturing and steam electric requirements.

Facilities can meet the stormwater requirements by including stormwater in their individual NPDES permit or seeking coverage under a general permit by submitting a Notice of Intent (NOI). Individual permit control and monitoring requirements will be facility-specific, subject to the judgment of the permit writer.

When covered by a general stormwater permit, requirements include implementation of a stormwater pollution prevention plan, "reasonable and appropriate" control measures, and 1 or 2 years of monitoring and reporting. No site visit by regulators is required under the general permit. Under the general permit approach, non-utilities have a great deal of flexibility in selecting appropriate control measures for runoff that may have contacted CCWs. The general permit requirements include recommended best management practices for stormwater at steam electric facilities, landfills, treatment works, and construction areas greater than 5 acres. Because these requirements are additive across industrial sectors, if the hypothetical chemical manufacturer described above also operated an onsite ash landfill, that facility would have to meet landfill requirements in addition to chemical manufacturing and steam electric requirements.

Because the stormwater program is relatively new and managed only by authorized states, the number of facilities with general versus individual permits is not known. EPA handles NOIs for 10 nonauthorized states. In these states, 700 steam electric facilities (both utility and non-utility) have filed for general permits.

4.5.3 Regulations Addressing Solid and Hazardous Waste

EPA regulates the management of solid and hazardous waste through Subtitles C and D of the federal Resource Conservation and Recovery Act (RCRA). Subtitle C of RCRA establishes a “cradle-to-grave” management system for wastes that are considered hazardous because they fail tests based on their physical and chemical characteristics (i.e., toxicity, corrosivity, ignitability, and reactivity) or because they are listed as hazardous by EPA. Federal regulations establish stringent environmental and administrative controls that must be applied to the management of these wastes. Non-utility coal combustion wastes are currently exempt from federal regulation as hazardous waste under Subtitle C pending this Report to Congress and the subsequent regulatory determination. Therefore, these wastes currently are subject to the requirements of Subtitle D of RCRA as nonhazardous solid waste.

Implementation of Subtitle D is the responsibility of individual states, but nothing prevents states from imposing more stringent requirements (including hazardous waste requirements) on FFC wastes. Currently, 44 states (representing 87 percent of non-utility coal-fired electrical generation capacity) duplicate the federal policy exempting CCWs from hazardous waste regulations. The six remaining states (Kentucky, Tennessee, Washington, New Jersey, Maine, and California) do not exempt CCWs from hazardous waste regulation. In these states, non-utility CCWs that fail the hazardous waste characteristic tests are subject to hazardous waste requirements. These wastes, therefore, must be managed in units that meet permitting, design, operating, corrective action, and closure standards.

Based on available characterization data, however, non-utility CCWs seldom are expected to fail the hazardous waste characteristic tests. The majority of non-utility CCWs would be subject to state requirements under Subtitle D because they do not fail the hazardous waste tests and/or are generated in the 44 states that duplicate the federal exemption. States generally regulate onsite waste management units that handle only non-utility CCWs using the same regulatory approaches used for utility CCW management units. They often regulate units, both onsite and offsite, that manage non-utility CCWs along with other nonhazardous industrial wastes in accordance with industrial Subtitle D programs. These programs are expected to be essentially the same as those applicable to CCW-only management units. Detailed review of regulations in several states supports the view that states regulate non-utility CCWs in the same manner as utility CCWs.

Table 4-8 shows data on state regulatory authority with respect to non-utility CCW landfills. These data show that the majority of states have the authority to require permits and to impose physical controls and monitoring requirements on non-utility landfills, at least on a case-by-case basis. The types of regulatory controls include siting controls, liners, leachate collection systems, ground-water monitoring, closure controls, daily (or other operational) cover, and fugitive dust controls. EPA believes that the use of such controls has the potential to mitigate risks, particularly ground-water pathway risks, from comanaged waste disposal. The sufficiency of this mitigation depends on the extent to which states are exercising their authority in situations in which climate, geology, site-specific conditions, and waste characteristics affect the magnitude of the risk.

Table 4-8. State Regulatory Controls on Non-Utility Coal Combustion Waste Landfills

	Number of States[b]	Percent of States[c]	Percent of Capacity[d]
Hazardous Waste Exemption[a]	44	88%	87%
Permit Onsite	41	82%	82%
Permit Offsite	48	96%	96%
Siting Controls	46	96%	89%
Liners	43	86%	88%
Leachate Collection Systems	42	84%	81%
Ground-Water Monitoring	46	92%	90%
Closure Controls	45	90%	94%
Cover and/or Dust Controls	49	98%	96%

[a] Exemption from state hazardous waste regulations for coal combustion wastes
[b] Number of states with authority to impose the indicated requirement, either by regulation or on a case-by-case basis
[c] Percent of surveyed states with authority
[d] Percent of surveyed generating capacity represented by states with authority
Sources: CIBO, 1997c; ASTSWMO, 1995; EPA, 1995b; and ACAA, 1996a

Section 4.3 summarizes the use of regulatory permits and environmental controls at non-utility waste management units. The available data suggest that states have exercised their authority to impose controls, although perhaps to a lesser extent at non-utilities than at utilities. To further examine state implementation of solid waste requirements on non-utility CCWs, EPA examined in greater detail the regulations applicable in five states: Indiana, Pennsylvania, Wisconsin, North Carolina, and Virginia. These five states account for more than 20 percent of coal-fired non-utility electrical generation capacity. Table 4-9 summarizes the requirements in each of these five states. Because surface impoundments are uncommon for non-utilities, this analysis focuses on landfill regulations.

Based on this detailed analysis, it appears that state requirements have become increasingly stringent over time. States vary in their approaches to regulating non-utility CCW landfills. For example, programs in Indiana and Pennsylvania impose requirements tailored to the characteristics of the waste. North Carolina may impose requirements based on site-specific modeling. In Virginia, requirements apply generically to all industrial wastes. Wisconsin may modify its requirements specifically for landfills designed to receive coal combustion ash. In several of the states studied, CCWs may be disposed of in older landfills that are “grandfathered” out of requirements imposing design requirements such as liners.

Table 4-9. State Waste Management Requirements Applicable to Non-Utility CCWs in Selected States

Indiana	
Landfill Requirements	Landfills are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the landfill. Based on available characterization data, most non-utility CCWs would be amenable to Type III landfills. Requirements for these include clay liner (thickness of 3 feet), siting restrictions, fugitive dust control, weekly cover, soil erosion control, 2-foot clay cap at closure, and revegetation at closure. Leachate collection systems are not required but may be used in some cases to relax the liner thickness requirements.
Grandfather Clause	Facilities that existed prior to September 1989 may continue to operate, but any expansions at these facilities must comply with the requirements above.

Pennsylvania	
Landfill Requirements	Landfills are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the landfill. Based on available characterization data, most non-utility CCWs would be amenable to Class III landfills. Requirements for these include siting restrictions, a 4-foot attenuating soil base (or 1-foot-per-4-feet of waste), fugitive dust control, daily cover, soil erosion control, ground-water monitoring, 2-foot clay cap at closure, and revegetation at closure.
Grandfather Clause	Units permitted prior to July 4, 1992 were required to modify their operations to comply with the above requirements by July 4, 1997. Liner and leachate collection requirements may be modified if the operator can demonstrate that the unit has not caused unacceptable ground-water degradation.
Minefill Requirements	CCWs must meet TCLP limits for disposal at a Class III landfill. Ground-water monitoring is required.
Soil Amendment Requirements	CCWs must meet pH limits. State agency notification and runoff and erosion controls are required. There are siting limitations.
North Carolina	
Landfill Requirements	Industrial waste landfills must demonstrate that their design will ensure that the state ground-water standards are not exceeded at the compliance boundary. The design criteria for demonstrating this include a composite liner, leachate collection system, and cap at closure. Alternatively, the operator may submit ground-water modeling results that demonstrate, based on hydrologic and climatic conditions and waste characteristics, that the standards will be met.
Grandfather Clause	To continue operating after January 1, 1998, landfills operating prior to October 1, 1995 must demonstrate that their original design or proposed design changes will meet the ground-water standards. The state has the authority to require design modifications if ground-water modeling methods or results are inadequate.
Wisconsin	
Landfill Requirements	Requirements include clay or composite liners, leachate collection systems, fugitive dust controls, 2-foot clay cap at closure, revegetation at closure, and ground-water monitoring. The state may modify the requirements for landfills designed to receive “high-volume” industrial waste, specifically coal ash waste, on a case-by-case basis.
Grandfather Clause	Landfills with plan of operations approved prior to July 1, 1996, are exempt from liner and leachate collection requirements. For landfills constructed prior to February 1, 1988, the state may require ground-water monitoring on a case-by-case basis.
Virginia	
Landfill Requirements	There are separate programs for industrial landfills and sanitary landfills. While sanitary landfills primarily manage household waste, they are allowed to receive nonhazardous industrial solid wastes, such as CCWs. Offsite landfills may be either industrial or sanitary landfills; onsite landfills are expected to be industrial landfills. For industrial landfills, design requirements include leachate collection systems, run-on controls, liner (1 foot of compacted clay or equivalent), cap at closure, fugitive dust controls, and ground-water monitoring. A double liner system in which the primary liner is synthetic may be used in lieu of ground-water monitoring. For fly ash and bottom ash from the combustion of fossil fuels, periodic cover or dust control measures such as surface wetting or crusting agents are required. For sanitary landfills, design requirements include leachate collection systems, run-on and run-off controls, composite liner, cap at closure, revegetation at closure, daily cover, fugitive dust control, and ground-water monitoring. Air pollution control residues (such as fly ash) should be incorporated into the working face of the landfill and periodically covered to prevent them from becoming airborne.

Grandfather Clause	Landfills permitted prior to 1988 must submit a monitoring plan, but may continue operating without retrofits as long as they do not expand.
Minefill Requirements	Use in structural fills, mine reclamation, or mine refuse disposal requires notification and development of design, operation, and closure plans. CCWs thus used must not exceed the toxicity characteristic levels for metals. Fugitive dust and run-on and runoff controls and 18 inches of cover at closure are required.
Soil Amendment Requirements	Agricultural uses of CCW are exempt from the solid waste regulations provided they meet the requirements of the Virginia Department of Agriculture and Consumer Services.

4.6 WASTE MANAGEMENT ALTERNATIVES

The risk assessment identified potential ground-water pathway risks to human health from non-utility CCWs managed in unlined landfills. Mitigation of these potential risks might be accomplished through the use of technologies that prevent or contain and collect leachate from non-utility CCW landfills. Specifically, EPA identified the combination of technologies in Table 4-10 as an alternative that would be practical and effective to target and mitigate the potential ground-water risk. The technologies shown in Table 4-10 are considered further in the cost and economic impact analysis (Section 4.7). Section 4.7 includes the option of sending waste to an offsite commercial landfill employing these technologies as well as the option of constructing such a unit on site. Note that these technologies are consistent with those required under Subtitle D of RCRA.

Table 4-10. Management Alternatives for Non-Utility Coal Combustion Waste

Landfill
Design includes filter fabric, 1' sand layer, 2' clay liner, synthetic high-density polyethelene (HDPE) liner, leachate collection system, and ground-water wells. Operation includes environmental monitoring, leachate collection and treatment. Closure requirements include 6" topsoil and vegetation, filter fabric, 1.5' sand layer, 2' clay layer, synthetic (HDPE) liner, and a cover drainage system. Post-closure includes environmental monitoring, landscape maintenance, slope maintenance, inspection, and administration.

In addition to landfill disposal, agricultural use may be of environmental concern, based on the above-ground risk assessment that found potential arsenic risks to human health from this practice. An approach for mitigating this potential risk might include a standard limiting the arsenic concentration in wastes intended for this use. Because of the small quantity of waste potentially affected, EPA has not estimated cost for such an alternative. Minefilling also may be of concern, particularly when wastes are placed below the water table. EPA is seeking further information on this practice.

4.7 COMPLIANCE COSTS AND ECONOMIC IMPACTS

This section discusses the costs and economic impacts of risk mitigation alternatives for non-utility CCWs. Details of this analysis, together with a background describing the variety of industries represented, are documented as part of the EPA docket.

4.7.1 Overview and Methodology

In estimating costs and economic impacts for non-utilities, EPA used a similar approach to that described in Section 3.7.1 for coal-fired utilities. Salient distinctions between the utility analysis and this non-utility analysis are reviewed below.

EPA's analysis for non-utilities began with 958 facilities identified in the 1990 U.S. EPA National Interim Emissions Inventory database (EPA, 1990). EPA estimated the incremental compliance cost of the risk mitigation alternative described in Section 4.6. As described in that section, this requires generators to construct onsite composite-lined landfills or transport waste to an offsite commercial Subtitle D landfill. The more economical method was assigned to each plant depending upon its estimate annual CCW generation rate.

The cost estimate summed costs in five categories: initial capital costs, recurring capital costs, annual operating and maintenance costs, closure costs, and annual post-closure costs. The specific components included in each cost category were the same as those in the utility analysis (see Section 3.7.1). As in the utility analysis, the cost estimate employed three different landfill sizes. Table 4-11 identifies the design features for non-utility landfills.

As in the utility analysis, a single cost equation was developed, annualized costs were estimated as a function of facility-specific waste generation, and total industry costs were derived by summing the facility-specific estimates. Costs and economic impacts are set forth in the following three sections: incremental compliance cost, compliance cost impact on facilities as a function of size, and industry impact. Incremental compliance costs are the costs of risk mitigation practices *over and above* the cost of current management practices. Using incremental compliance costs as an indicator of potential cost burden, the analysis examined impacts on individual facilities as a function of size. Unlike for the utility analysis, this was performed using industry average sales for only the average and large facilities. Detailed financial profiles of representative "model" facilities were not developed for the non-utility sector because of the data collection requirements and multiplicity of facilities involved.

For the industry impact evaluation, the use of econometric models was considered and rejected because of the diversity of industrial and institutional sectors potentially affected. The industry-level analysis, therefore, focuses on the same two measurements used in the utility analysis: the number of affected facilities and the magnitude of incremental compliance costs relative to the value of electricity sales.

4.7.2 Incremental Compliance Cost

EPA's estimate of incremental compliance cost for non-utility coal combustors is approximately $103 million per year. This compliance cost would be distributed across the range of industries represented by non-utility combustors. Table 4-12 summarizes the details of this cost estimate by non-utility industry SIC code. As with the utility sector, delayed compliance, were this to be considered, would result in far lower costs.

Note that the costs shown are incremental (above current costs). Annual costs were discounted at 7 percent to 1998 dollars, with no inflation built into out-year estimates. Also, it was presumed that compliance would be required immediately, and that amortization would take place over 40 years.

Table 4-11. Design Parameters Assumed for Small, Medium, and Large Landfills

Parameter		Non-Utility Ash Landfill
Sizes	small	150
(tons/year)	medium	5,000
	large	15,000
Depth		Pile design
(feet)	small	1.0
	medium	1.0
	large	1.0
		Combination fill design
	small	3.3
	medium	17.4
	large	43.6
Height		Pile design
(feet)	small	15.0
	medium	25.0
	large	25.0
		Combination fill design
	small	4.3
	medium	22.2
	large	28.1
Area		Pile design
(acres)	small	0.4
	medium	5.6
	large	15.7
		Combination fill design
	small	0.5
	medium	3.5
	large	6.5

Note: Landfill designs considered include a "pile design" constructed primarily above grade and a "combination fill design" constructed both above and below grade.

4.7.3 Compliance Cost Impact on Facilities as a Function of Size

EPA believes that the ability of industry to pass through cost increases will be limited because only a small share of plants within the affected industries operate coal-fired boilers. Competition from unaffected facilities would restrict the ability of facilities facing incremental compliance costs to increase prices. Therefore, this analysis includes no analytical consideration of price effects.

As discussed previously in this chapter, non-utility CCWs are generated by a wide variety of industrial and institutional facilities that generate electricity or energy for primarily internal use. In general, the affected facilities represent a small share of an industry or economic sector, and fossil fuel use and costs are a relatively small part of production inputs and costs. The most common types of facilities affected include pulp and paper mills, food processing facilities, chemical manufacturers, cement manufacturers, and educational institutions/universities.

The order of magnitude of expected facility-level impacts can be demonstrated by examining one industry sector as an example. In 1992, the Bureau of the Census reported there were about 15,000

Table 4-12. Cost Estimates for Non-Utility CCW (1998 million $/yr, annualized)

SIC Code	Industry	Number of Facilities	Incremental Costs
20	Food and Kindred Products	98	$9.7
21	Tobacco Manufactures	11	$0.9
22	Textile Mill Products	59	$3.2
25	Furniture and Fixtures	35	$0.1
26	Paper and Allied Products	140	$24.4
28	Chemicals and Allied Products	114	$23.8
29	Petroleum and Coal Products	12	$0.7
30	Rubber and Miscellaneous Plastics Products	21	$1.5
32	Stone, Clay, and Glass Products	17	$1.3
33	Primary Metal Industries	44	$4.1
34	Fabricated Metal Products	21	$1.2
35	Industrial Machinery and Equipment	26	$1.6
36	Electric and Electronic Equipment	15	$0.9
37	Transportation Equipment	61	$3.4
49	Electric, Gas, and Sanitary Services	44	$12.3
80	Health Services	58	$2.5
82	Educational Services	77	$5.3
92	Justice, Public Order, and Safety	26	$0.9
97	National Security and International Affairs	17	$0.7
Other SICs		53	$4.5
Unknown SICs		9	$0.3
Totals		**958**	**$103.3**

establishments engaged in food processing (SIC 20) with an annual value of shipments of $281 billion. Based on these numbers, the average food processing facility had approximately $19 million per year in sales. In comparison, only 98 food processing facilities—those burning coal—would be expected to incur incremental compliance costs. Annualized, these costs are estimated to be $9.7 million, or about $100,000 per facility per year. Thus, for this industry, less than 1 percent of the facilities would incur any impacts. The cost would equal about 0.5 percent of annual sales for each facility.[4] Most affected facilities, however, are expected to be relatively large as only large facilities can usually justify captive coal-fired boiler operations. In 1992, the food processing industry contained 2,788 facilities that employed 100 or more employees. These larger facilities had a combined value of shipments of

[4] In these estimates, sales are in 1992 dollars and compliance costs in 1998 dollars. Therefore, the figures shown may overestimate impacts.

$225 billion or $81 million per facility. Thus, if the 98 affected facilities were all large, still only 1 in 30 would be affected and the incremental compliance costs would be 0.1 percent of annual sales.

Table 4-13 shows similar comparisons for other major non-utility industry sectors. The sectors presented include food processing facilities, pulp and paper mills, chemical manufacturers, primary metals manufacturers, and transportation equipment manufacturers. Together, these five industries account for approximately 80 percent of non-utility CCW generation, based on data from the 1990 U.S. EPA National Interim Emissions Inventory. In general, facilities in these sectors should not incur significant overall cost burdens; however, the incremental cost could significantly affect their energy use practices by causing some facilities to switch from internal generation to external purchase, similar to the practices of most facilities in the affected industries, to avoid the regulatory burden and to obtain cheaper energy.

Table 4-13. Facility-Level Economic Impacts, Non-Utility CCW

Sector	Number of Affected Facilities	Facility Size	Average Facility Sales (1992 $ million/yr)	Average Facility Incremental Compliance Cost (1998 $ million/yr)	Compliance Cost as a Percentage of Sales
Food Processing	98	Average Large	$19 $81	$0.10 $0.10	0.5% 0.1%
Pulp and Paper	140	Average Large	$118 $151	$0.17 $0.17	0.2% 0.1%
Chemical Manufacturing	141	Average Large	$26 $157	$0.21 $0.21	0.8% 0.1%
Primary Metals	44	Average Large	$21 $85	$0.09 $0.09	0.4% 0.1%
Transportation Equipment	61	Average Large	$35 $217	$0.06 $0.06	0.2% 0.03%
Note: Large facilities are establishments with more than 100 employees.					

4.7.4 Industry Impacts

This analysis addresses the major non-utility industries shown in Table 4-14. For example, the food processing sector would incur incremental costs of $9.7 million per year; however, the food processing sector was a $448-billion-per-year industry in 1995. Thus, incremental compliance costs would represent less than 0.002 percent of overall market value. Moreover, only about 1 out of every 150 facilities would be affected directly. Similar results are evident for other major non-utility industry sectors, as shown in Table 4-14.

4.8 FINDINGS AND RECOMMENDATIONS

4.8.1 Introduction

Based on the information collected for this Report to Congress, this section presents a summary of the Agency's main findings presented under headings that parallel the organization of this chapter. It then presents the Agency's tentative conclusions concerning the disposal and beneficial uses of wastes generated at non-utilities, including wastes from the burning of coal and petroleum coke and the coburning of other fuels with coal as identified in this chapter.

Table 4-14. Industry-Level Economic Impacts, Non-Utility CCW

Sector	Industry Sales ($billion/yr)	Incremental Compliance Cost ($billion/yr)	Compliance Cost as a Percentage of Sales
Food Processing	$448	$0.010	0.002%
Pulp and Paper	$52	$0.024	0.050%
Chemical Manufacturing	$362	$0.024	0.010%
Primary Metals	$180	$0.004	0.002%
Transportation Equipment	$463	$0.003	0.001%
Other Industrial/Institutional	Not estimated	$0.026	---
Note: Sales are in 1995 dollars and compliance costs in 1998 dollars. Therefore, the percentages shown may overestimate impacts.			

4.8.2 Findings

Sector Profile

- There are no comprehensive data on industry-wide generation of non-utility coal combustion wastes. The Agency was able to characterize the sector profile based on major stationary point sources of air emissions but not the smaller combustors. On this basis, the Agency identified 958 major non-utility burners of coal, petroleum coke, and other fuels that are coburned with coal. The eastern United States has a larger concentration of these facilities than the western United States.

- There are approximately 2,300 boilers in operation at the major non-utility facilities.

- Non-utilities burn these fuels for a variety of purposes, including manufacturing process steam production, hot water, space heating, and captive electric power generation. They include industrial, commercial, and institutional facilities. They are located in diverse environments, including areas that vary widely in population density, geography, precipitation, and general climate.

Waste Generation and Characteristics

- Non-utility burners of coal and petroleum coke generate the same types of large-volume and low-volume wastes as utilities. They employ the same types of combustion technologies and combustion support processes as the utilities. The major non-utility facilities generate nearly 6-million tons per year of the high-volume wastes.

- Wastes from non-utility burners appear to be similar to their counterpart utility wastes. Similarly, the constituents of concern are trace metal elements, particularly the eight RCRA metals.

- The total quantities of low-volume wastes generated at these facilities is not well established; however, the aggregate quantities are much lower than utility low-volume wastes.

Waste Management Practices

- Landfills appear to be the predominant type of waste management unit for the disposal of wastes. Limited information suggests that the majority of combustion wastes are disposed in *offsite* landfills. Surface impoundments appear to be the only other type of waste management unit employed, and they are infrequently used.

- Combustion wastes are more frequently comanaged with low-volume wastes or a diverse range of other (unrelated) industrial wastes as opposed to separate management.

- Comprehensive statistics are not available on the amounts of these wastes that serve beneficial uses. Available information suggests that use of these materials as a component in cement and concrete and as construction fill are the most common beneficial uses.

Potential Risks and Damage Cases

- EPA conducted a risk assessment that found a lack of potential human health risk for virtually all waste constituents. Arsenic was the one constituent for which the Agency identified potential human health risks via the ground-water pathway where the combustion wastes are managed alone or comanaged with low-volume wastes in landfills. The identified risk is based on high-end risk scenarios in EPA's risk modeling analysis for human ingestion of well water influenced by releases from the waste management unit. The time to reach the health-based level for arsenic in ground water at the receptor well is estimated to be in excess of 1,400 years.

- EPA conducted a risk assessment that found a lack of potential human health risk for virtually all waste constituents. Arsenic was the one constituent for which the Agency identified potential human health risks via non-ground-water pathways where these wastes are used as soil amendments for agricultural purposes. The identified risk is based on high-end risk scenarios in EPA's risk modeling analysis for human ingestion exposure routes.

- No ecological risks were identified for management of wastes in this sector.

- No damage cases were identified for this sector that exclusively involve these wastes, although this finding is based on rather limited information. Two superfund National Priority List sites were identified that involve coal combustion wastes. These sites are considered to be damage cases, but other wastes unrelated to the generation of CCWs were comanaged at these sites, and there is uncertainty about the contributing influences of the CCWs. Arsenic was identified as a constituent of concern in these two damage cases, but because of the mixed wastes, it could not be conclusively attributed to the CCW component.

- Some natural arsenic levels in U.S. soils have the potential to pose higher risks than the risk identified with the level of arsenic contributed by these wastes for non-ground-water pathways.

Existing Regulatory Controls, State and Federal Requirements

- The major facilities in the non-utility sector have a significant level of installed environmental controls for these wastes that mitigate the potential human health risks identified in this study.

- States have increasingly begun to impose controls on these wastes. The states vary somewhat in their approaches to regulating these wastes; however, in aggregate, there is existing state authority to impose substantial regulatory controls on these wastes. For example, there exists authority at the state level to impose siting controls, liners requirements, leachate collection systems, and permit procedures for more than 80 percent of the generated wastes. There exists additional authority at the state level to impose ground-water monitoring requirements, closure controls, and dust/cover controls for more than 90 percent of the generated wastes.

Potential Costs and Impacts of Regulation

- The Agency estimates that the total annual incremental compliance costs for mitigation of the potential arsenic risks identified in this study would be approximately $100 million (1998$). These costs represent replacement of existing unlined management units with lined management units, and implementing ground-water monitoring and leachate collection and treatment. These measures do not represent implementation of full Subtitle C requirements, but rather modifications of such requirements that could potentially be adopted under Section 3004(x) of RCRA.

- If these wastes were to be regulated under full Subtitle C, virtually all existing facilities would be required to invest substantial funds and resources to modify existing management practices. The total annual cost of full Subtitle C requirements would considerably exceed the $100 million (1998 $) estimate above.

- If beneficial uses of theses wastes were subject to Subtitle C requirement, possibly all beneficial use practices and markets would cease.

4.8.3 Recommendations

Following are the Agency's recommendations for the wastes covered in this chapter. The recommendations are based on EPA's analysis of the eight Congressionally mandated study factors (Section 1.2). These conclusions are subject to change based on continuing information collection, continuing consultations with other government agencies and the Congress, and comments and new information submitted to EPA during the comment period and any public hearings on this report. The final Agency decision on the appropriate regulatory status for these wastes will be issued after receipt and consideration of comments as part of the Regulatory Determination, which will be issued within 6 months.

1. *The Agency has tentatively concluded that disposal of these wastes should remain exempt from RCRA Subtitle C.*

As with the utility coal combustion wastes addressed in Chapter 3, the Agency has tentatively concluded that the non-utility CCWs, including wastes from petroleum coke combustion and from other fuels that are co-fired with coal, and also low-volume wastes where they are managed with the combustion wastes, generally present a low inherent toxicity, are seldom characteristically hazardous, and generally do not present a risk to human health and the environment. State programs increasingly require more sophisticated environmental controls at these types of facilities. There are few damage cases and none of the identified damage cases exclusively involved these wastes or affected human receptors. These types of facilities are typically located in areas of low population and thus present infrequent opportunity for human exposure. The Agency believes that no significant ecological risks are posed by disposal of these wastes. The predominant practice is to manage these wastes in landfills, with a much lower frequency of using impoundments. Environmental controls are common at the landfills. For example, nearly all implement ground-water monitoring and runoff controls, and two-thirds have leachate collection. Overall, the Agency believes that when these wastes are disposed, regulation under Subtitle C authority is not warranted. For the issues discussed below involving agricultural use and management of these wastes in mines (minefill), the Agency is still considering whether some regulation under RCRA Subtitle C may be warranted.

There is a very small segment of non-utility coal burners that generates mill rejects, a low-volume waste, that may be comanaged with the CCWs. The Agency has the same concerns about the potential for problem management situations involving pyritic materials as described for utilities in Chapter 3. Although the Agency did not identify any of these situations at non-utility facilities during this study, it is engaging the non-utility sector in a program to ensure that these particular wastes are appropriately managed. This effort parallels the pyrites management program described for utilities in Chapter 3. EPA will follow-up with oversight on the industry's management of these wastes, and will revisit this issue if necessary.

2. *The Agency has tentatively concluded that most beneficial uses of these wastes should remain exempt from Subtitle C.*

No significant risks to human health and the environment were identified or believed to exist for any beneficial uses of these wastes, with the possible exception of minefill and agricultural use as discussed below. This is based on one or more of the following reasons for each use or resulting product: absence of identifiable damage cases, fixation of the waste in finished products which immobilizes the material, and/or low probability of human exposure to the material.

3. The Agency is tentatively considering the option of subjecting practices involving the use of these wastes for agricultural purposes (i.e., as a soil nutrient supplement or other amendment) to some form of regulation under Subtitle C.

As mentioned above, the Agency identified potential risk from exposure to arsenic in these wastes when they are used for agricultural purposes. The risks identified with this practice may be of sufficient concern to consider whether some form of control under Subtitle C is appropriate, given the increasing trend for use of these materials as agricultural amendments. An example of such controls could include regulation of the content of these materials such that arsenic concentrations could be no higher than that found in agricultural lime. On the other hand, imposition of controls under Subtitle C may not be warranted if sufficient protection may be afforded by the Agency engaging the industry to establish voluntary controls on this practice. An example of such voluntary controls could consist of an agreement to limit the level of arsenic in these materials. The Agency solicits comment on its tentative conclusion and specific approaches that could be pursued to address the concern.

Non-utility burners of coal, particularly those that generate significant quantities of combustion wastes, may have opportunities for their wastes to be minefilled, that is, permanently placed in mine voids similar to the practice with some utility combustion wastes. As discussed in Chapter 3, the Agency currently lacks sufficient information with which to adequately assess risk associated with this practice and, therefore, to decide whether this practice should remain exempt from Subtitle C. For the same reasons discussed in Chapter 3's recommendations, the Agency solicits comment on whether there are some minefill practices that are universally poor and warrant specific attention. EPA also seeks comment on whether coal or other fossil fuel combustion wastes used as minefill and placed in direct contact with the water table would create environmental concerns, and if that specific practice should be regulated. The Agency's focus is on potential risks that may be posed via the ground-water and surface pathways from use of these wastes as minefill.

5.0 FLUIDIZED BED COMBUSTION WASTES

Fluidized bed combustion (FBC) is an emerging technology for the combustion of fossil and other fuels. Coal is the most common fossil fuel burned by FBC facilities, although some facilities burn waste coal, petroleum coke, or other fuels. This chapter covers FBC wastes from facilities combusting all types of fossil fuels (e.g., including petroleum coke). FBC makes up only a portion of the fossil fuel combustion (FFC) universe—approximately 1 percent of fossil fuel-fired capacity. The potential for increased use of the technology and the potential differences in waste characteristics, however, led EPA to consider FBC wastes separately from coal combustion wastes from conventional technologies in its 1993 Regulatory Determination (58 FR 42466, 8/9/93). For the same reasons, FBC is presented separately for analysis in this report.

SECTOR OVERVIEW

FBC technology is used in both the utility and non-utility sectors. Approximately half of the facilities using FBC technologies are utilities or independent power producers. Facilities in the food products and pulp and paper industries, along with educational institutions, make up most of the non-utility FBC facilities. Other industries represented include chemicals and allied products, petroleum refining, transportation equipment, wholesale trade, and research services. Also included are municipal government buildings and one correctional facility.

Although FBC technology accounts for a small proportion of capacity relative to the other sectors considered in this report, use of the technology has increased dramatically over the last 20 years. In 1978, there were four plants with four FBC boilers in the United States. As of December 1996, there were 84 facilities with 123 FBC boilers representing 4,951 megawatts of equivalent electrical generating capacity (CIBO, 1997c). Furthermore, the fuel flexibility, efficiency, and emissions characteristics of FBC boilers are such that use of the technology has the potential to increase in the future.

Figure 5-1 shows the geographic distribution of FBC facilities. While these facilities are distributed throughout the United States, Pennsylvania and California account for the largest numbers of plants. Pennsylvania accounts for more than 20 percent of capacity and California more than 10 percent. As discussed in Section 5.3, FBC facilities practice both onsite and offsite waste management. Offsite waste management units are located near the generating facility in most cases. Therefore, the geographic distribution of combustion facilities presented in Figure 5-1 also is generally representative of the universe of waste management unit locations.

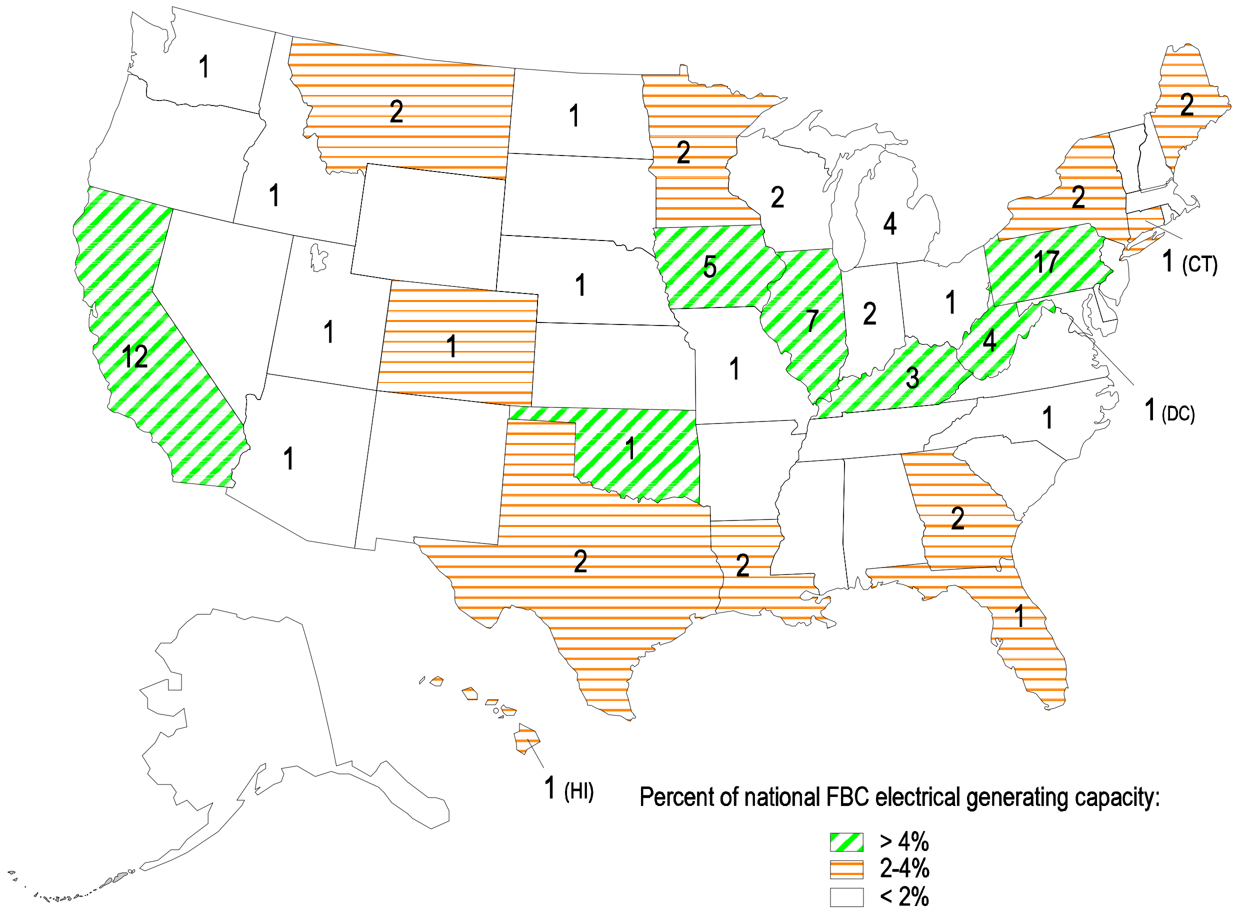
5.1 WASTE GENERATION

The two main waste streams generated in FBC processes are listed below:

- **Bed ash (or bottom ash).** Spent bed material and fuel ash removed from the boiler bottom.
- **Fly ash.** Ash removed from the entrained air stream.

As for the wastes from conventional combustion technologies discussed in Chapters 3 and 4, the generation of FBC wastes is governed by combustion technology (Section 5.1.1), air pollution control technology (Section 5.1.2), and fuel usage (Section 5.1.3). Unlike the wastes from conventional technologies, FBC wastes comprise not only uncombusted material from the fuel, but also spent incombustible bed material, as discussed below.

Figure 5-1. Number of Fluidized Bed Combustion Facilities by State



Source: CIBO, 1997c

No comprehensive industry-wide data exist on the generation of FBC wastes. In 1996, however, in support of this study, the Council of Industrial Boiler Owners (CIBO) sent a voluntary questionnaire to every fossil fuel-fired FBC plant, both utility and non-utility, in the United States (CIBO, 1997b). This survey collected general facility information, characterized process inputs and outputs, gathered data on waste generation and characteristics, and captured details of FBC waste management practices. Thirty-nine FBC facilities provided waste generation information in response to the survey. By extrapolating from the generation rates reported by these 39 respondents, CIBO estimates total FBC waste generation in 1995 to be between 9,091,600 and 13,150,560 short tons, with the most likely estimate being 9,417,500 short tons (CIBO, 1997c). This estimate is only about 10 percent of the total quantity of utility CCWs generated, because there are far fewer FBC facilities, most of which have lower capacity than a typical utility. On a per-megawatt basis, however, FBC units generate a larger quantity of waste than comparable conventional combustion units. The reasons for this increased waste generation are discussed in the sections below.

Like conventional combustors, FBC units generate low-volume combustion wastes as a result of supporting processes (see Section 5.1.4) that are ancillary to, but a necessary part of, the combustion and power generation processes. These low-volume wastes include the following:

- **Coal pile runoff.** Runoff and drainage produced by precipitation falling on coal storage areas (not generated at petroleum coke-fired FBC facilities).

- **Coal mill rejects.** Produced by onsite processing of coal prior to use (not generated at petroleum coke-fired FBC facilities).

- **Boiler blowdown.** Waste that is continuously or intermittently removed from boilers that recirculate water.

- **Cooling tower blowdown and sludge.** Wastes removed periodically from closed-loop cooling systems.

- **Water treatment sludge.** Wastes resulting from treatment of make-up water for the steam cycle or for non-contact cooling.

- **Regeneration waste streams.** Wastes resulting from periodic cleaning of ion exchange beds used to remove mineral salts from boiler make-up water.

- **Air heater and precipitator washwater.** Wastes resulting from the periodic cleaning of the fireside (i.e., the side exposed to hot combustion products) of heat exchanging surfaces.
- **Boiler chemical cleaning waste.** Wastes resulting from the periodic cleaning of the inside (waterside) of boiler tubes with chemical solutions.

- **Floor and yard drains and sumps.** Wastewaters collected by drains and sumps, including precipitation runoff, piping and equipment leakage, and wash water.

- **Laboratory wastes.** Wastes generated in small quantities during routine analysis of coal, intake water, wastes, and other samples at a plant site.

- **Wastewater treatment sludge.** Sludge generated from the treatment in settling basins or other treatment facilities of any or all of the liquid waste streams described above.

FBC facilities would be expected to generate smaller quantities of these wastes, consistent with their smaller unit size (see Section 5.1.1). In some cases, other characteristics of FBC technology may reduce the generation of some of these wastes (see Section 5.1.4).

In addition to FBC wastes and low-volume combustion wastes, non-utility FBC facilities have the potential to generate a wide range of non-combustion process wastes, consistent with the variety of industries represented by these facilities. These process wastes may be managed together with combustion wastes. No comprehensive data exist on the quantity of these non-combustion process wastes generated at non-utility FBC facilities.

5.1.1 Fluidized Bed Combustion Technology

Box 5-1 provides a general overview of FBC technology. Such technology presents several advantages over conventional processes in terms of fuel flexibility, combustion efficiency, and reduction of emissions:

- **Fuel Flexibility**. The temperatures in FBC systems are below the ash softening temperature for most fuels. In addition, the mixing of fuel with incombustible bed material creates a high thermal inertia. These conditions allow for stable ignition and combustion of even low grade fuels and make the FBC process insensitive to fuel characteristics such as moisture and ash content (Stultz and Kitto, 1992).

- **Combustion Efficiency**. FBC processes allow for efficient combustion even at the low temperatures used because of the relatively long residence time of fuel in the bed, the heat transfer between incombustible bed material and fuel, and the gas/solids contact created by the fluidizing conditions (CIBO, 1997c).
- **Emissions Control**. The low temperatures also limit the generation and emission of nitrogen oxides. Furthermore, a sorbent material, typically limestone, often makes up a portion of the bed material. This sorbent, along with the low temperature, allows the efficient capture of sulfur oxides (CIBO, 1997c).

The FBC technologies discussed in Box 5-1 operate at atmospheric pressure. An advanced form of FBC, called Pressurized Fluidized Bed Combustion (PFBC), currently is under development. PFBC systems are similar to other FBC systems, but operate under pressure. Because of the pressurized operation, the combustion air in PFBC systems contains more oxygen per unit volume, allowing more intense combustion in smaller combustion units. Also, because the combustion off-gases are pressurized, they can be passed through both a turbine and a steam boiler in sequence, allowing greater combustion efficiency. Only one PFBC system currently is in operation at the commercial scale (EERC, 1997) and this facility is a research facility. Because this emerging technology has not yet received commercial application, limited data are available on PFBC wastes and waste management practices. Therefore, this chapter applies to wastes from the more developed atmospheric FBC systems.

Box 5-1. Fluidized Bed Combustion (FBC) Technology

In FBC processes, fuel is burned on a bed of incombustible material (e.g., sand and limestone) while combustion air is forced upward at high velocities, making the particles flow as a fluid. The fuel typically is a solid (frequently coal), although FBC can burn gas and liquid fuels as well. When coal is fed to an FBC boiler, it usually is crushed to 0.25 inches, a size between that used by stokers and pulverizers. FBC temperatures are below those for conventional processes—bed temperatures are maintained between 1,500°F and 1,600°F. The bed material often includes a sorbent, such as limestone, that allows the capture of sulfur oxides without the end-of-stack scrubbers often required for conventional coal combustion processes. There are two primary types of FBC systems: bubbling fluidized beds and circulating fluidized beds. The differences between the two depend mainly on the bed particle diameter and gas flow velocity.

Bubbling fluidized bed systems have air velocities of 5 to 12 feet per second and larger bed particle size. These conditions result in a dense bed (45 pounds per cubic foot) with a well-defined surface. Excess air passes through the bed in the form of bubbles. A small amount of bed material entrained in the gas stream (a maximum of 25 percent of the combustion gas weight) may be recycled back to the furnace to maximize combustion efficiency and sulfur capture.

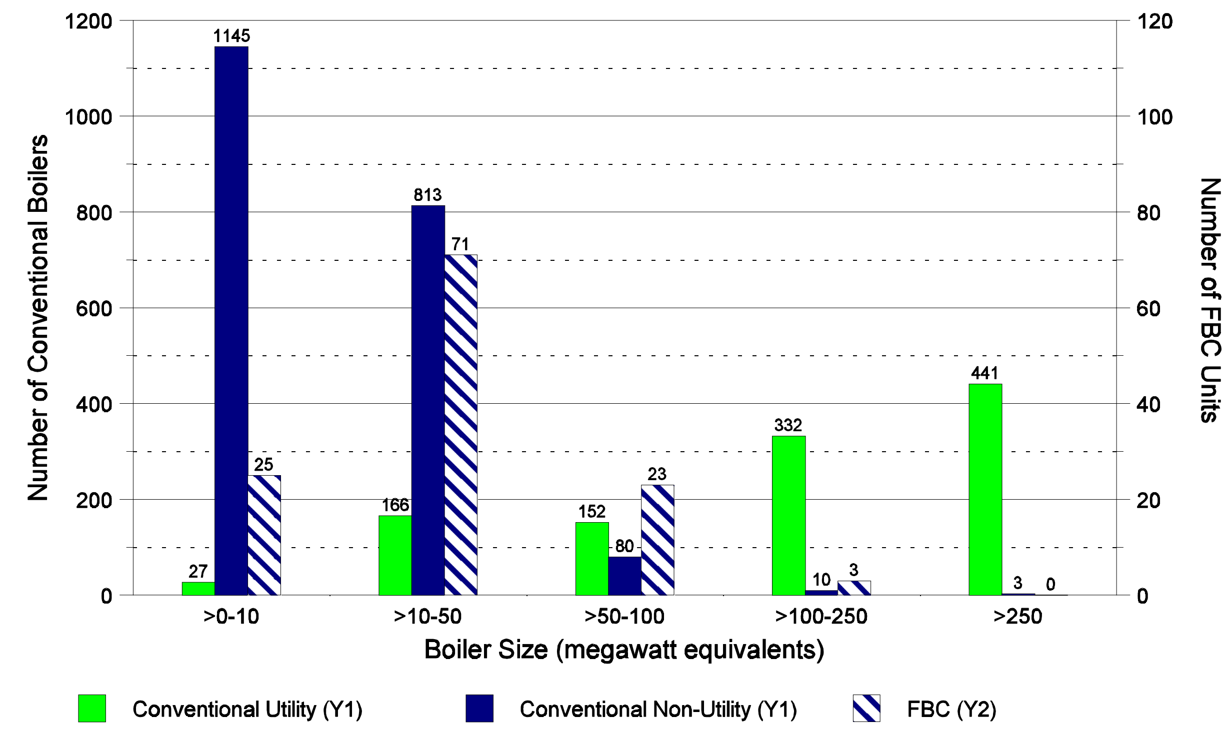
Circulating fluidized bed systems have greater air velocities (as high as 30 feet per second) and finer particle sizes. As a result, the fluid bed is less dense (35 pounds per cubic foot) and has no well-defined top surface. Bed and fuel material are distributed uniformly throughout the furnace, although density declines as particles move upward. Particle entrainment increases in these systems such that large quantities of bed material must be recaptured from the gas stream and recirculated back to the furnace to maintain bed inventory.

Sources: CIBO, 1997c; Stultz and Kitto, 1992; Elliott, 1989

The partitioning of FBC waste between fly ash and bed ash depends on combustion technology. In bubbling fluidized beds, waste generated is mostly bed material: fuel ash, lime (if used as sulfur sorbent), calcium sulfate (formed by the reaction of sulfur with the sorbent), and sand or other inert bed material. On the other hand, fly ash represents most of the waste generated by circulating fluidized beds (Stultz and Kitto, 1992).

In general, FBC facilities are small in capacity. Figure 5-2 compares the capacity distribution of FBC units to that of conventional coal-fired boilers in both the utility and non-utility sectors. Figure 5-3 shows the distribution of utility and non-utility FBC units in each capacity category. Utility FBC units, although larger on average than non-utility FBC units, are smaller than typical conventional coal-fired utility boilers. Non-utility FBC units are similar in capacity to the small conventional boilers used by non-utilities. As a result of their small capacity, FBC units would be expected to generate less waste on a per-boiler basis, all other factors being equal. Also, the high combustion efficiency of FBC units would tend to result in lower waste generation on a per-unit basis. The presence of spent bed and sorbent materials and the potentially greater ash content of the fuel, however, more than counteract this reduction, as discussed in Section 5.1.3.

Figure 5-2. Capacities of Conventional and FBC Boilers

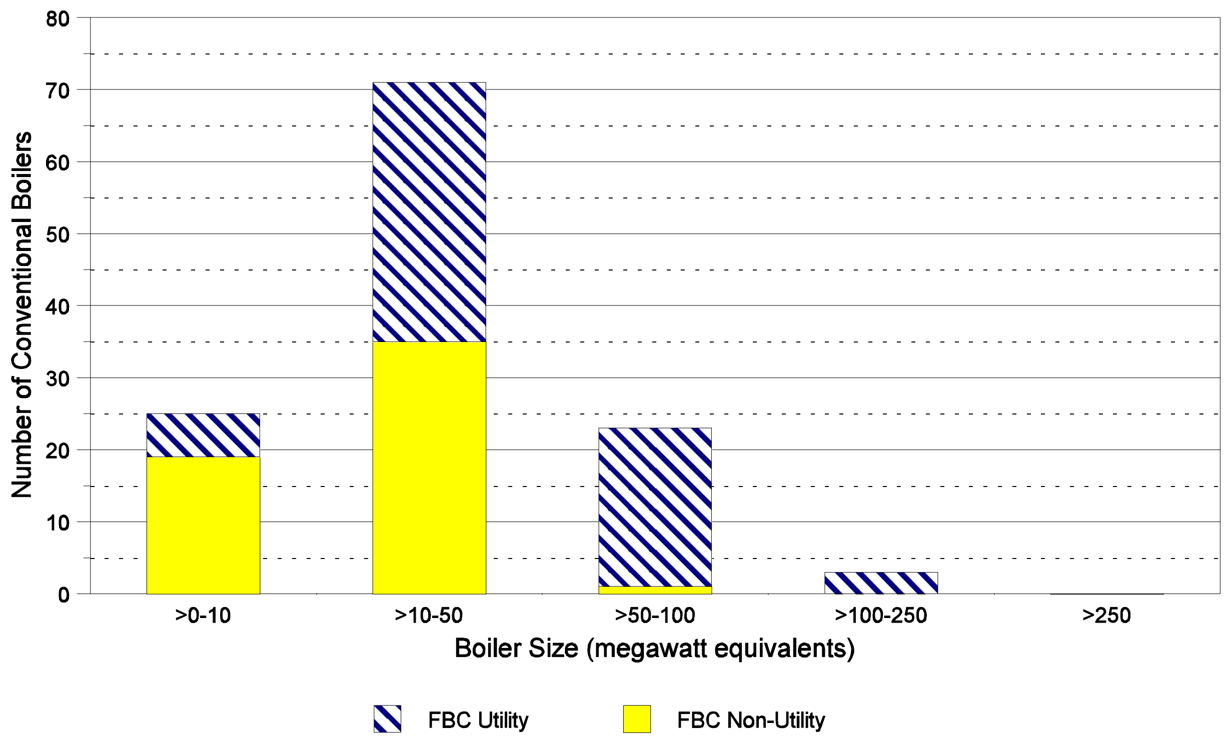


Sources: EEI, 1994; EPA, 1990; CIBO, 1997b; CIBO, 1997c

5.1.2 Air Pollution Control Technologies

Just like conventional combustion facilities, the capture of FBC fly ash is governed by the particulate control technology used. Fly ash leaving the boiler must be removed from the gas stream in which it is entrained or it will be released to the atmosphere. Because FBC technologies capture sulfur oxides using a sorbent within the combustion bed, they do not require the application of separate flue gas

Figure 5-3. Capacities of Utility and Non-Utility FBC Units



Sources: EEI, 1994; EPA, 1990; CIBO, 1997b; CIBO, 1997c

desulfurization (FGD) technologies; however, FBC units can use the same basic particulate control technologies as those used at conventional coal-fired utilities. Chapter 3 describes these technologies.

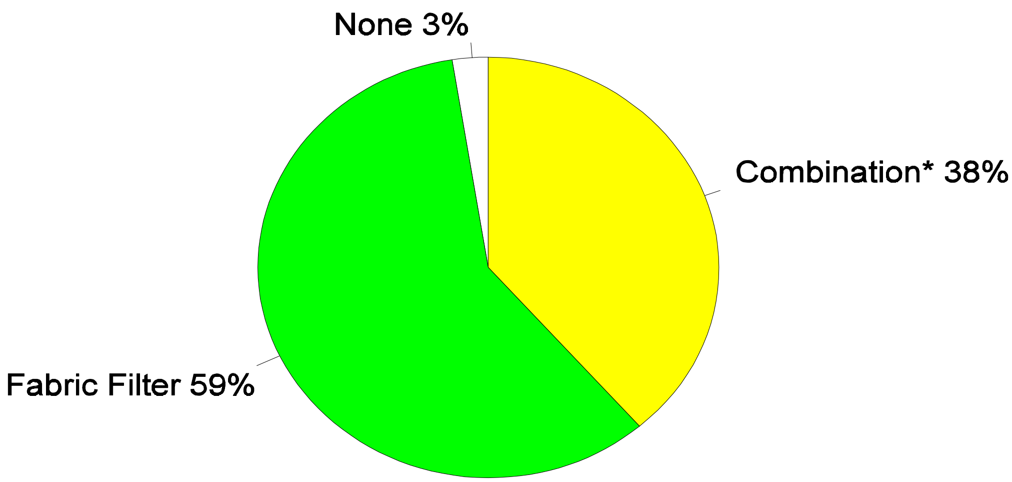
Figure 5-4 shows data on particulate control devices used at FBC facilities. FBC units are as likely as conventional coal-fired utilities to apply particulate controls. This is due to two factors. First, all circulating fluidized bed processes use some form of particulate control to accomplish the recirculation of bed material. Second, all FBC facilities are relatively new. Thus, they are subject to regulatory controls on air emissions despite their smaller size, as discussed in Section 5.5. FBC facilities tend to use fabric filters for particulate control rather than the electrostatic precipitators (ESPs) that are common for coal-fired utilities. Like ESPs, however, fabric filters provide for efficient collection of fly ash.

5.1.3 Fuel and Sorbent Use

The quantity of FBC waste generated is affected by the ash content of the fuel. Ash content is, in part, determined by the rank of the coal: anthracite, bituminous, subbituminous, or lignite. In addition to coal rank, ash content depends on the specific coal-producing region, mine, seam, and production method. Because of their fuel flexibility, FBC boilers burn a wider range of fuels than do conventional coal-fired boilers. Table 5-1 shows the primary fuels used by facilities responding to the CIBO FBC Survey.

FBC facilities that burn coal show a breakdown by coal rank similar to that observed for conventional coal facilities: primarily bituminous, followed by subbituminous and lignite. Some FBC facilities, however, may burn coal with higher ash content than conventional boilers. Furthermore, in addition to coal, FBC facilities burn waste coal and other fuels. Waste coal includes culm (anthracite

Figure 5-4. Particulate Control Technologies Used at FBC Facilities



*Mechanical collector followed by fabric filter or ESP.
Note: Percentages shown are of 39 facilities providing particulate information.
Source: CIBO, 1997b

Table 5-1. Primary Fuels Used by FBC Facilities

Type of Fuel	Fuel	Number of Facilities	Mass of Fuel (tons)	Percent of Total Mass
Coal	Anthracite Coal	0	0	0%
	Bituminous Coal	20	7,384,624	42%
	Subbituminous Coal	4	2,306,910	13%
	Lignite Coal	2	2,086,227	12%
Waste Coal	Anthracite Culm	6	2,604,863	15%
	Bituminous Gob	5	2,089,268	12%
Other	Petroleum Coke	5	895,658	5%
	Natural Gas	1	191,601	1%
Total		43	17,559,151	100%
Source: CIBO, 1997b				

coal refuse) and gob (bituminous coal refuse) and results from the coal-cleaning processes used to separate standard coal from its impurities. Waste coals are higher in ash and lower in carbon content (and therefore lower in fuel value) than standard coals. Several FBC facilities reported burning petroleum coke as a primary fuel. Petroleum coke is the heavy residual from petroleum cracking processes. Its characteristics vary widely depending on the process used. One facility reported burning natural gas (CIBO, 1997c).

While smaller capacities and greater efficiency may reduce waste generation at FBC facilities relative to that at conventional coal-combustion facilities, the use of higher ash content fuels at some facilities tends to counteract this reduction. The presence of spent bed and sorbent materials further counteract this reduction. Spent bed and sorbent material can compose a significant proportion of the waste generated from FBC technology. Table 5-2 presents data on the types and quantities of sorbent and bed material used by FBC facilities in 1995. Limestone is the most commonly used material and serves as a sorbent for sulfur dioxides. Sand is the most common incombustible bed base. Other materials include clay and gravel as bed material and ammonia and urea to control nitrogen oxide emissions.

Table 5-2. Sorbent and Bed Materials Used at FBC Facilities

Non-Combustible Commodities	Number of Plants	Total Annual Usage (tons)
Limestone	36	2,420,820
Sand	20	16,154
Other	7	3,002
Total	63	2,439,976
Source: CIBO, 1997b		

5.1.4 Supporting Processes

The generation of low-volume combustion wastes primarily is associated with processes that support the combustion process or make use of the products of combustion. Some of the same supporting and enabling processes can accompany combustion at FBC facilities as at conventional facilities, including the following:

- Coal storage
- Coal processing
- Steam generation
- Cooling
- Water treatment
- Cleaning and maintenance.

Chapter 3 describes these processes in detail. The paragraphs below describe potential differences in these processes at FBC facilities with respect to waste generation. Little quantitative information is available on the quantities of low-volume combustion wastes generated at FBC plants.

Coal Storage and Processing

The FBC population includes a large percentage of small capacity units. These small capacity units are less likely to store large quantities of fuel onsite than conventional coal-fired utilities. Therefore, these facilities are less likely to generate coal pile runoff than conventional coal-fired utilities. Also, because of their fuel feed tolerance, FBC plants are less likely to conduct onsite coal cleaning than conventional coal-fired utilities. Therefore, FBC plants generally do not generate coal mill rejects (pyrites). No information is available on wastes from the storage and processing of fuels other than coal (e.g., petroleum coke).

Steam Generation, Cooling, and Water Treatment

These processes generate wastes including boiler blowdown, cooling tower blowdown, water treatment wastes, and regenerant wastes. The quantities of these wastes generated are related to the quantity of water used in the steam and cooling cycles, which in turn is related to combustion capacity. Because of their smaller capacity, FBC units generally use less water in the combustion process than conventional utilities and, therefore, may generate smaller quantities of these wastes. In addition, some non-utility FBC plants may use steam directly for heat in industrial processes rather than to generate electricity. In some cases, this practice may reduce the need for cooling, and in turn reduce the generation of wastes associated with the cooling cycle.

Cleaning and Maintenance

Cleaning processes intermittently generate low-volume wastes including air heater and precipitator washwater and boiler chemical cleaning waste. Because of the lower operating temperatures compared to conventional coal combustion technologies, FBC units may require less frequent cleaning than conventional boilers. The small capacities of some units also may require smaller quantities of cleaning solutions than required at conventional coal-fired utilities. These factors can result in lesser generation of cleaning wastes at FBC units than at conventional coal combustors.

5.2 WASTE CHARACTERISTICS

5.2.1 Physical Characteristics

FBC fly ash is a solid composed of fine particles, similar in size to that generated by pulverized coal combustors. Sixty to 90 percent of FBC fly ash particles are finer than 100 microns. FBC fly ash particles are less rounded than those from conventional combustion processes because of the lower combustion temperatures. FBC bed ash also is a solid particulate, with a size that varies depending on fuel and sorbent characteristics. FBC bed ash particle size varies from 0.1 to 2 millimeters (CIBO, 1997c).

5.2.2 Chemical Characteristics

Both FBC fly ash and bed ash contain non-combustible mineral matter, sorbent material, and unburned carbon. The major constituents of FBC waste are calcium, sulfur, silicon, iron, aluminum, magnesium, and potassium. As with conventional coal combustion waste (CCW), most of these constituents are present in the form of oxides. Due to the presence of sorbent material, however, FBC wastes have a higher content of calcium and sulfate and a lower content of silica and alumina than conventional CCWs (CIBO, 1997c). In addition, the amount of unburned carbon in FBC ash is quite small because of the low concentration of fuel in the bed. The carbon content in a fluidized bed burning bituminous coal typically is less than 1 percent (Stultz and Kitto, 1992). Like conventional CCWs, FBC waste constituents include trace metals. Table 5-3 presents typical concentrations for these constituents.

Leachate and Hazardous Waste Characteristics

Using data available on the composition of FBC wastes, EPA evaluated whether the waste exhibited any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and toxicity. Based on available information and engineering judgment, EPA does not believe that FBC wastes are reactive, ignitable, or corrosive. FBC waste cannot be considered corrosive under EPA's definitions because the characteristic does not apply to solid materials.

Table 5-3. Facility Average Concentrations of Trace Constituents in FBC Wastes (parts per million)

Constituent	Fly Ash		Bed Ash		Combined Ash	
	Mean	Range	Mean	Range	Mean	Range
Antimony	33.4	0.125–259	40.1	0.125–361	14.3	0.065–62
Arsenic	38.1	2.8–176	25.1	2.5–80	25.1	1.4–77.2
Barium	542	31.3–2,690	190	7.3–453	258	39.2–690
Beryllium	3.31	1.08–11.5	3	0.5–8	2.97	0.148–9.5
Boron	366	0.025–2,470	79.1	0.025–304	149	1.25–1,670
Cadmium	1.79	0.013–6.68	1.79	0.0125–7.16	1.53	0.009–5.9
Chromium	46	5.17–97.1	36.4	4.1–86	43.7	12–181
Cobalt	22.3	2.5–79.8	16.9	1.4–75.8	5.6	0.6–18.7
Copper	40.5	2–99	17.5	1.65–37.1	40.1	1.9–192
Lead	30.3	1.03–105	18.9	0.848–58	23.2	0.45–67
Manganese	223	0.05–548	311	52.2–751	88.7	20–211
Mercury	7.86	0.00005–129	1.43	0.00005–16.2	0.431	0.0113–1.68
Molybdenum	13.9	2.35–48.6	20.8	6–63.4	9.65	0.125–41
Nickel	179	6.25–923	190	1–945	142	0.77–985
Selenium	19.5	0.47–166	5.45	0.152–45	5.86	0.404–18
Silver	2.35	0.05–11.6	8.75	0.05–87.6	2.75	0.479–21.8
Thallium	9.46	1.25–39	7.63	0.5–25	5.56	0.09–12.5
Vanadium	771	36.4–3,830	987	12–5,240	144	26.3–5,000
Zinc	53	24–143	64.7	17.4–399	3150	11–45,300

Notes: Encompasses wastes generated by facilities burning all types of fuel reported in the CIBO survey (i.e., coal, waste coal, and petroleum coke). All measurements identified as below detection limit were assigned a value equal to one-half the detection limit for use in the calculations. All concentrations are facility-averaged; i.e., multiple measurements from a single site were averaged, and the resulting population of facility averages was used to generate the statistics in this table.
Source: CIBO, 1997b

EPA evaluates the characteristic of toxicity using Toxicity Characteristic Leaching Procedure (TCLP) results. Table 5-4 presents typical TCLP results for FBC wastes for a number of constituents. These include the eight metals regulated under the Resource Conservation and Recovery Act (RCRA) and several other constituents. Data also are available from Extraction Procedure (EP) tests (a test previously used by EPA to evaluate toxicity) for many of these same constituents. The EP results are generally similar to or lower than the TCLP results shown in Table 5-4. The exceptions are antimony, arsenic, chromium, mercury, and zinc in fly ash and aluminum, beryllium, and zinc in bed ash, which appear in EP results at somewhat higher levels. The discussion below addresses the leachate data first for RCRA-regulated constituents, then for non-RCRA-regulated constituents.

Table 5-4. Facility Average TCLP Results for FBC Wastes (mg/l)

Constituent	RCRA Standard	Fly Ash		Bed Ash		Combined Ash	
		Mean	Range	Mean	Range	Mean	Range
RCRA Toxicity Constituents							
Arsenic	5.0	0.0498	0.0125–0.17	0.0369	0.0025–0.125	0.102	0.0023–0.365
Barium	100.0	3.40	0.0175–42	0.613	0.025–2.5	1.22	0.0223–10.5
Cadmium	1.0	0.0193	0.0005–0.09	0.0175	0.0005–0.051	0.0181	0.00125–0.096
Chromium	5.0	0.0577	0.01–0.141	0.0526	0.0025–0.14	0.0667	0.0033–0.25
Lead	5.0	0.113	0.0025–0.505	0.0715	0.0025–0.235	0.13	0.001–1
Mercury	0.2	0.000661	0.00005–0.00192	0.00116	0.00025–0.005	0.00198	0.00005–0.0169
Selenium	1.0	0.0739	0.002–0.2	0.0415	0.002–0.158	0.0584	0.00413–0.175
Silver	5.0	0.0258	0.005–0.053	0.0533	0.005–0.25	0.0253	0.0038–0.145
Non-RCRA Constituents							
Antimony	n/a	0.224	0.0095–0.66	0.218	0.025–0.52	0.121	0.00065–0.27
Beryllium	n/a	0.00947	0.00005–0.025	0.01085	0.00005–0.025	n/a	n/a
Boron	n/a	0.447	0.06–0.76	1.328	0.13–2.6	3.2	0.0367–26.7
Cobalt	n/a	0.0725	0.0025–0.19	0.125	0.025–0.225	0.106	0.0065–0.4
Copper	n/a	0.042	0.0025–0.077	0.0403	0.0275–0.0633	0.0574	0.00188–0.203
Manganese	n/a	0.190	0.00125–0.6	0.403	0.05–1.27	0.208	0.00208–0.507
Molybdenum	n/a	0.168	0.11–0.32	0.16	0.119–0.2	0.108	0.0125–0.21
Nickel	n/a	0.0926	0.0025–0.3	0.119	0.0167–0.28	0.121	0.0025–0.46
Thallium	n/a	0.0229	0.0208–0.025	0.0356	0.025–0.0463	n/a	n/a
Vanadium	n/a	0.105	0.025–0.185	0.941	0.025–1.858	n/a	n/a
Zinc	n/a	0.111	0.0025–0.35	0.141	0.015–0.51	0.114	0.0025–0.38

n/a = data not available
Notes: Encompasses wastes generated by facilities burning all types of fuel reported in the CIBO survey (i.e., coal, waste coal, and petroleum coke). All measurements identified as below detection limit were assigned a value equal to one-half the detection limit for use in the calculations. All concentrations are facility-averaged; i.e., multiple measurements from a single site were averaged, and the resulting population of facility averages was used to generate the statistics in this table. Statistics presented here are based on a varying number of samples, depending on the constituent. For details, refer to the *Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Waste Characterization*.
Source: CIBO, 1997b

Based on the TCLP and EP data for the eight RCRA metals, FBC wastes rarely exhibit the RCRA characteristic of toxicity. Only one FBC site of 24 (4 percent) for which data are available had any samples of waste for which TCLP or EP analyses exceeded the regulatory threshold. At this site, a facility that burns waste coal, the only sample of fly ash analyzed for mercury exceeded the threshold for that metal.[1]

In addition, as shown in Table 5-4, TCLP data (and, in some cases, EP data) are available for a number of other non-RCRA-regulated constituents, including antimony, beryllium, boron, cobalt, copper, manganese, molybdenum, nickel, thallium, vanadium, and zinc. These constituents of potential concern are considered further in Section 5.4 along with the eight RCRA-regulated metals for their potential risk to human health and the environment.

A few respondents to the CIBO survey also provided data on organic constituents in FBC waste leachate. Of 102 analyses for various organics from seven facilities, 97 (or 95 percent) were below detection limits. The five analyses above detection limits were from a single facility. This facility reported concentrations of 0.1 milligrams per liter (mg/l) each for benzene, chlorobenzene, 1,4-dichlorobenzene, trichloroethylene, and tetrachloroethylene. These concentrations are well below the RCRA regulatory threshold for these constituents (0.1 mg/l compared to 0.5 mg/l, 100 mg/l, 7.5 mg/l, 0.5 mg/l, and 0.7 mg/l for each constituent, respectively). Analyses for 24 other organics at the same facility were below detection limits. The leachate data presented in this section include facilities burning all types of fuel. There is a possibility that facilities burning petroleum coke may leach higher concentrations of certain metals, due to higher concentrations of these metals in the fuel. To investigate this possibility, EPA compared TCLP and EP results for FBC facilities burning petroleum coke to those for facilities burning other fuels (mainly coal). The available data on petroleum coke-fired FBC wastes are sparse. On a constituent-by-constituent basis, data are available for a maximum of three of the five petroleum coke-fired facilities. In addition, the majority of samples are below detection limits for all constituents other than barium, vanadium, and zinc. Although the data are somewhat limited, trace constituent concentrations for petroleum coke-fired FBC wastes are similar to or less than levels in coal-fired FBC wastes, except for vanadium.[2] Thus, coal-fired FBC wastes are considered the bounding case in terms of waste characteristics, and EPA relied on the coal-fired FBC data in its risk assessment analysis for FBC wastes.

5.3 CURRENT MANAGEMENT PRACTICES

Unlike the other wastes covered by this study, the majority of FBC waste is not disposed in traditional waste management units. Instead, most FBC waste is beneficially used, primarily in minefilling. Sections 5.3.1 through 5.3.4 characterize the management units used for that portion of FBC waste that is disposed. Section 5.3.5 covers beneficial uses and minefilling.

Two sources of data are available to characterize management practices for FBC wastes. The first is the CIBO FBC survey (CIBO, 1997b) conducted in 1996. In addition, four of the landfills covered in the Electric Power Research Institute (EPRI) utility comanagement survey (EPRI, 1997a), also conducted in 1996, reported managing FBC waste. One of these facilities responded to the CIBO FBC

[1] At another facility, one sample for selenium was reported as a non-detect with a detection limit more than twice the regulatory level. If assigned a value of one-half the detection limit according to the approach used in this report, the sample would be counted as an exceedence; however, given that no other samples exceeded the regulatory threshold for selenium, this apparent exceedence was assumed to be an artifact of the high detection limit and not counted here.

[2] The facility average TCLP concentration of vanadium at the single petroleum coke-fired facility for which data are available was 1.86 mg/l for bed ash and 0.185 mg/l for fly ash. By comparison, all vanadium analyses were below detection limits at the single coal-fired facility where vanadium was sampled.

survey, but the other three did not. The EPRI responses from these three additional units are analyzed here along with the CIBO responses. This analysis treats the CIBO respondents plus the three EPRI respondents as a single sample. The 23 facilities in this sample cover 27 percent of all U.S. facilities using FBC. The estimated quantity of FBC waste managed by the surveyed waste management units is about 2.1-million tons per year, or 22 percent of the total estimated FBC waste generated. The sample facilities include utilities and non-utilities and are geographically representative of the full population, with the exception that Pennsylvania and Illinois appear to be underrepresented in the sample.

5.3.1 Unit Types and Locations

The 23 facilities in the combined sample reported a total of 25 waste management units: 12 onsite landfills, 5 offsite landfills, 4 onsite surface impoundments, and 4 units of unknown type. These data show landfilling as the most common FBC waste management practice, accounting for 81 percent of the units whose type (i.e., landfill or surface impoundment) is known. The proportion of landfills for FBC wastes is greater for FBC wastes than for utility CCWs. In addition, of the four impoundments identified, three are operated by the same company. The fourth impoundment is a conventional utility CCW management unit in which FBC wastes also are disposed. Therefore, EPA believes the identified impoundments represent unusual cases.

The FBC waste management units in the sample are relatively new. One of the surface impoundments was constructed in 1974, but the remaining units all were constructed after 1981. This may be due to the relatively recent adoption of FBC technology. New facility construction may include new waste management units to serve the facility. Where this new facility construction includes FBC technology (as opposed to cases in which FBC is a retrofit at an older facility), the FBC waste would consequently be managed in these new waste management units. The age distribution of FBC waste management units also may help explain the predominance of landfills, if the FBC sector follows the general trend found for utility CCW management (see Section 3.3).

5.3.2 Types and Volumes of Wastes Managed

The two types of FBC waste, fly ash and bed ash, are frequently combined and managed together. Combined management with other, non-FBC wastes, however, is less common for FBC wastes than for other types of FFC waste. Only 10 (or 40 percent) of the 25 FBC waste management units for which data are available reported managing FBC wastes with other wastes. In addition, two of the offsite landfills did not report comanagement, but are described as municipal solid waste landfills. Presumably, in these landfills, FBC wastes are managed along with municipal solid waste, bringing the total to 12 units (48 percent) that practice combined management. This compares to comanagement by 84 percent of conventional utility CCW management units.

In management units that combine FBC wastes with other wastes, the types of waste managed are as variable for FBC waste management units as those for CCW management units. The types of waste comanaged include conventional CCWs, low-volume combustion wastes (e.g., metal cleaning wastes, cooling tower blowdown, boiler blowdown, regenerant wastes, and coal pile runoff), and non-combustion wastes (e.g., municipal waste, wastewater treatment sludge, dredged soils, wastepaper deinking sludge, and construction debris). One facility, a utility with a conventional coal boiler in addition to an FBC boiler, comanages coal mill rejects. The quantities of non-FBC waste managed range from several times to a fraction of the quantity of FBC waste.

5.3.3 Unit Size

Table 5-5 shows summary statistics on the dimensions of FBC waste management units. These data show that FBC waste management units are smaller than typical conventional utility CCW management units (see Section 3.3). While most FBC landfills are clustered around the median size, two units in the population are much larger, with capacities of 5-million and 6.1-million cubic yards.

Table 5-5. FBC Waste Management Unit Sizes

	Landfills			Surface Impoundments		
	Capacity (cubic yards)	Area (acres)	Height (feet)	Capacity (cubic yards)	Area (acres)	Depth (feet)
Number of Units	13	11	10	3	2	2
Minimum	350,000	17	17	2,240,000	28	70
Maximum	6,100,000	96	75	5,600,000	55	125
Median	1,500,000	38	52	4,000,000	41	98
Mean	2,063,461	38	51	3,946,667	41	98

Note: Not all units in the sample reported all three measurements (area, height or depth, and capacity). Where a unit reported two of the three dimensions, the third was derived from the other two. For example, if a landfill reported only capacity and area, the design height was calculated by dividing the reported capacity by the area.
Sources: CIBO, 1997b; EPRI, 1997a

5.3.4 Environmental Controls

The CIBO FBC survey collected information on liners, covers, leachate collection systems, ground-water monitoring systems, and regulatory permits. These environmental controls are defined in Chapter 3. The CIBO FBC survey also collected information on several other types of environmental controls, described in Box 5-2.

Table 5-6 summarizes the use of environmental controls in FBC waste management units. Based on these data, the frequencies of environmental controls for FBC waste management units are similar to corresponding frequencies for utility comanagement units. The following discussion provides additional details on each type of environmental control.

Liners

As shown in Table 5-6, the frequencies of liner use for FBC waste landfills are similar to those for utility CCW units (see Section 3.3). Figure 5-5 displays the types of materials used for FBC landfill liners. One surface impoundment reported a synthetic liner. Two other impoundments reported being constructed on bedrock, while the fourth reported an *in situ* clay liner.

Covers, Compaction, and Dust Suppression

Based on the data in Table 5-6, FBC waste landfills appear less likely than utility CCW comanagement units to use covers (see Section 3.3). It is unclear, however, whether respondents interpreted the question about cover as relating to current daily or interim cover or final cover at closure. If responses relate to final cover, then the lower percentage for FBC waste landfills is not surprising. All of the respondents are currently active, and, therefore, would not have final cover and, as relatively new

Box 5-2. Environmental Control Technologies

Dust Suppression/Control. Dust suppression, typically used at landfills, usually involves conditioning the waste with water or other liquid before and during transport and placement. The purpose of this activity is to prevent airborne transport of waste and to reduce inhalation exposure to site workers.

Run-On and Runoff Controls and Collection Systems. Examples of run-on and runoff controls include curbs, dikes, and diversion ditches. Run-on controls prevent precipitation runoff from other parts of a site from reaching waste management areas, preventing this runoff from becoming contaminated by contact with waste and/or creating leachate by percolation through waste. Runoff controls and collection systems prevent precipitation runoff from the waste management unit, which may be contaminated by contact with waste or carry waste particles, from being transported offsite.

Compaction. Compacting waste after placement can reduce or prevent wind and water erosion of the waste and subsequent release to the environment. Under the right circumstances, where voids are minimized, compaction also can reduce the permeability of the waste, slowing the creation and release of leachate.

Surface Water and Air Monitoring Systems. Similar to ground-water monitoring systems, surface water and air monitoring systems comprise periodic collection and analysis of surface water or air samples near a waste management unit. These systems serve as a warning that a release is occurring through the air or that a surface water body is being contaminated.

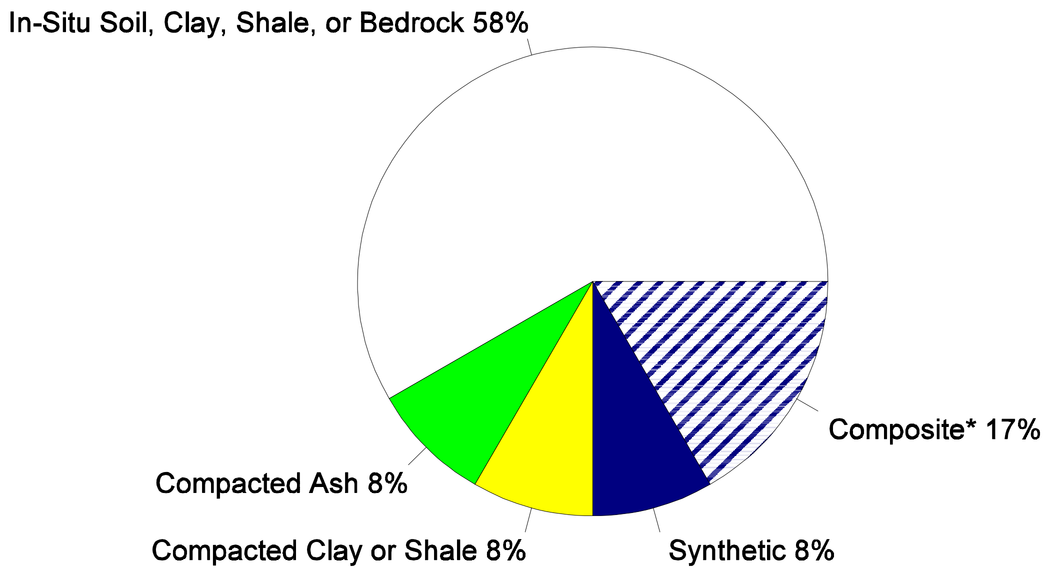
Table 5-6. Environmental Controls at FBC Waste Management Units

Environmental Control	Landfills		Surface Impoundments	
	Number Reporting Data	Percent with Control	Number Reporting Data	Percent with Control
Liner*	12	42%	4	25%
Cover	13	62%	3	67%
Leachate Collection	17	59%	4	50%
Run-on and Runoff Control and/or Collection	14	93%	4	100%
Dust Suppression	11	91%	3	67%
Compaction	11	55%	3	33%
Ground-Water Monitoring	16	77%	3	100%
Surface Water Monitoring	14	29%	4	50%
Air Monitoring	13	8%	3	0%
Regulatory Permits	17	89%	4	100%

*Does not count bedrock or other *in situ* materials as a liner.
Source: CIBO, 1997b; EPRI, 1997a

units, may not yet have plans for cover at closure. If responses relate to daily cover, the low number may be partially explained by the use of dust suppression and compaction (as controls with a similar purpose to daily cover). Nearly all FBC waste landfills use dust suppression and/or compaction.

Figure 5-5. FBC Landfill Liner Types



*Composite liners include synthetic and compacted clay layers.
Note: Percentages shown are of 12 landfills providing linea data. Percentages may not sum to 100 due to rounding.
Sources: CIBO, 1997b; EPRI, 1997a

Just like CCW comanagement units, the results for surface impoundments are difficult to interpret. The two impoundments reporting covers may have placed caps on closed or full portions. Alternatively, these units may have reported covers to reflect standing liquid maintained above the waste layer in the impoundment. For impoundments reporting compaction or dust suppression, the responses could be interpreted by three scenarios: (1) that compaction or dust suppression are used on dry, inactive, or closed areas of the impoundment; (2) that dust suppression or compaction are practiced during dry transport of waste, prior to placement in the impoundment; or (3) that waste is transported wet or wastes are managed under water in the impoundment, therefore preventing dust generation.

Regulatory Permits

As shown in Table 5-6, the proportions of FBC waste management units subject to permit requirements are similar to those for CCW comanagement units (see Section 3.3). Some of the respondents provided information about the permitting agency, as well as indicated whether the unit had one or more permits. Six of the surveyed units (four landfills and two impoundments) had multiple permits. In each case, the permitting agency was a state government, although one unit had both a state and a county permit.

5.3.5 Beneficial Uses

Like conventional CCWs, FBC wastes may be applied to useful purposes as an alternative to traditional waste management. In fact, according to CIBO survey statistics, the majority of FBC wastes currently are beneficially used. Table 5-7 shows data on the current developed uses of FBC wastes. The most dominant use of these wastes is in minefills, followed by waste stabilization, construction fills, and agricultural uses. Box 5-3 provides a brief discussion of these uses.

Table 5-7. Beneficial Uses of FBC Wastes

Use Category	Quantity (thousand tons)	Percent of Generation*
Mining Applications	3,629	61.0%
Waste Stabilization	351	5.9%
Construction Fills	302	5.1%
Agricultural Use	66	1.1%
Cement and Concrete Products	5	0.9%
Other	79	1.3%
Total	4,432	74.5%

* Percent of total waste generation reported by survey respondents.
Note: Percentages might not sum due to rounding.
Source: CIBO, 1997c

5.4 POTENTIAL AND DOCUMENTED DANGERS TO HUMAN HEALTH AND THE ENVIRONMENT

5.4.1 Potential Ground-Water Risks to Human Health

Section 3.4 provides a discussion of the methodology employed by EPA in assessing risks from coal-fired utility comanaged wastes. EPA followed a similar approach for wastes from fluidized bed combustion, with several important differences. First, waste characterization data for FBC wastes provided to EPA reflect wastes generated at a large portion of generators nationwide. All data were generated using TCLP or EP Toxicity methods, and these data were combined to provide as large a sample set as possible. Second, EPA found that very few FBC unit operators managed their wastes in impoundments. Moreover, the majority of these few impoundments are lined or constructed on bedrock. Therefore, EPA limited its modeling efforts to landfill scenarios. Finally, EPA found that FBC boilers reflect a geographic distribution distinct from utilities, and so modified its modeling scenarios accordingly.

Information provided by CIBO indicates that minefilling is common for FBC wastes. As discussed in Section 3.4.5, minefill risks were not evaluated using EPACMTP due to data and model limitations.

Findings–FBC Wastes Ground Water Human Health Risk Assessment

Table 5-8 summarizes selected results from the deterministic and probabilistic analyses of risk from FBC wastes for the adult receptor. Overall, EPA found that the risks associated with all modeled constituents of concern, except for antimony, arsenic, beryllium, and chromium, fell below a hazard quotient (HQ) of 1 or a lifetime cancer risk of 1×10^{-6}. Potential risks associated with arsenic in the high-end deterministic scenario exceeded 1×10^{-4}.

Comparison of the deterministic and Monte Carlo results reveals that the deterministic results generally exceed the 95th percentile Monte Carlo results. None of the 2,000 Monte Carlo simulation combinations of parameter values performed for any constituent yielded a risk estimate as high as the corresponding high-end deterministic result. Even at the 95th percentile level, the risks predicted by the Monte Carlo simulations were two orders of magnitude or more below the corresponding risks estimated for the high-end scenario.

Box 5-3. Beneficial Uses of FBC Wastes

Mining Applications. According to CIBO survey statistics, FBC wastes are most often utilized in mining applications. FBC wastes can be beneficially used in coal mine remediation activities, including the control of acid mining drainage, backfilling, blending mine soils and spoils, and revegetation. The alkaline characteristics of FBC wastes make them useful as a neutralizing buffer to dampen or eliminate the self-sustaining acid mining drainage generation. FBC waste has a significant quantity of unreacted sorbent (i.e., lime or limestone) that contributes to this buffer capability. FBC wastes mixed with conventional coal combustion fly ash and other mine spoils also have been used successfully. Another use of FBC waste is as backfill material to neutralize acidity at mine pits, and to prevent mine subsidence from abandoned underground mines. In order to neutralize the acidity of mine soils and spoils, significant quantities of mine wastes are mixed with FBC wastes. This also is performed in an effort to create a topsoil amenable to revegetation at mine sites.

Waste Treatment. FBC wastes also are applied in the treatment and management of hazardous waste. The primary objective of solidification and stabilization processes is to chemically fix potentially hazardous wastes in a solid matrix. Mixtures using FBC wastes have been found to stabilize the acidic components and trace constituents found in hazardous waste in a cost-effective manner.

Construction Fills. The granular and cementitious properties of FBC wastes and their free lime content are useful in various civil engineering applications. These wastes are applied as stabilizing agents in subgrade or subbase soils (e.g., road and road base construction, low-strength backfilling). Like lime, FBC wastes improve the compaction and load bearing capabilities and lower the plasticity of clays or silty soils. Moreover, FBC wastes introduce some degree of cementitious bonding not obtained with the addition of lime alone.

Agricultural Use. Besides increasing the pH of the soils, FBC waste also provides increased solubility. The gypsum contained in FBC waste has a significant impact on soil chemical and physical properties. Specifically, it has the potential to improve filtration, reclaim high sodium soils, increase rooting in acid subsoils due to the reduction of aluminum toxicity, and supply calcium and sulfur to plants. Increasing rates of FBC waste application have also been found to decrease soil extractable zinc, manganese, phosphorous, and potassium. Lastly, the ash content acts as a supplier of macro- and micro-nutrients essential to plant growth. The major problems associated with FBC residue use for agricultural purposes are high alkalinity and salinity, which may reduce plant growth at high application rates.

Cement and Concrete Products. The volume of FBC wastes used in concrete products has been minimal. Several factors including slow setting and expansion of the concrete product with time have been experienced, even when FBC wastes are mixed with fly ash. Still, studies are being conducted to understand the cementing action, strength development, and stability of concretes that use only FBC wastes and fly ash as binders (i.e., concretes that do not contain Portland cement).

Sources: CIBO, 1997c; EPA, 1998h

EPA also considered the time at which risks were predicted to result from the release of constituents of concern. EPA found that the concentration of arsenic in ground water at the receptor well would not reach the health-based level (HBL) for arsenic (i.e., achieve a risk level of 1×10^{-6}) for more than 3,000 years.[3] The times to reach the antimony HBL and the beryllium MCL in ground water were predicted to be nearly 6,000 years and greater than 6,500 years, respectively.[4]

[3] EPA, 1998d, p. 5–33.

[4] Ibid. Note that the time to risk calculated for beryllium in the draft report was the time to reach the CSF-based HBL. The MCL is greater than the HBL and so the time to reach the MCL must be at least as great as the time to reach the HBL.

Table 5-8. Comparison of Deterministic and Monte Carlo Risk Model Results for FBC Waste Ground-Water Pathway Scenario

Scenario	Constituent[a]	Deterministic Risk, Central Tendency	Deterministic Risk, High-End	Corresponding Monte Carlo Percentile	Monte Carlo 95th Percentile
FL[b]	Antimony	HQ <1	HQ = 12	>100	HQ = 0.007
	Arsenic	1×10^{-8}	4.3×10^{-4}	>100	2×10^{-6}
	Beryllium	HQ <1	HQ = 1.4	>100	HQ <0.001
	Chromium	HQ <1	HQ = 1.1	>100	HQ = 0.002

[a] All other metals modeled resulted in HQ <1
[b] FL = FBC waste landfill
Note: Results shown are those from the October 10, 1998, Sensitivity Analysis.

Considering the low hazard quotients, the very low probabilistic risk, and the long time to reach a level of risk for beryllium, antimony, and chromium, EPA eliminated these metals from further consideration for this pathway.

Table 5-9 summarizes the estimated risks to adult and child receptors for the high-end deterministic scenario for FBC wastes. Overall, the results show that for non-carcinogens the risks for young children increased roughly twofold compared with the adult receptors. For arsenic, risks changed very little between the receptors.

Table 5-9. Comparison of Adult and Child Risk Model Results for FBC Waste Ground-Water Pathway Scenario

Scenario	Constituent[a]	High-End Deterministic Risk		
		Deterministic Risk, Central Tendency	Deterministic Risk, High-End	Monte Carlo 95th Percentile
FL[b]	Antimony	HQ = 12	HQ = 20.8	HQ = 13.4
	Arsenic	4.3×10^{-4}	5.4×10^{-4}	3.8×10^{-4}
	Beryllium	HQ = 1.4	HQ = 2.4	HQ = 1.6
	Chromium	HQ = 1.1	HQ = 1.9	HQ = 1.2

[a] All other metals modeled resulted in HQ <1
[b] FL = FBC waste landfill
Note: Results shown are those from the October 10, 1998, Sensitivity Analysis.

5.4.2 Potential Above-Ground Multi-Pathway Risks to Human Health and the Environment

Human Health Risk Findings

No cancer risk in excess of 10^{-6} or non-cancer HQ in excess of 1 were found, except for agricultural application. Risks to farmer and child were approximately 10^{-5} for the pathway.

Ecological Risk Findings

No ecological risk was found, but EPA had no characterization data with which to assess FBC impoundments. Given that landfill risks for human health risk approximate those for utilities, it is likely, based on total constituent analysis, that ecological risks similar to those for utility impoundments would exist for the few reported FBC impoundments.

5.4.3 Documented Damages to Human Health and the Environment

EPA relied on a report prepared by CIBO to assess releases and damage cases to human health or the environment involving FBC wastes (CIBO, 1997c). In addition, while not specifically directed at FBC non-utilities, EPA's examination of state file information for non-utilities in six states did not identify any additional incidents related to FBC waste management sites. This indicates that the state officials contacted were unaware of any damage cases related to FBC non-utilities. EPA has not specifically pursued other references to further identify other FBC waste management sites with documented releases or damages.

The CIBO report identified eight sites managing FBC wastes where ground- or surface-water contamination was observed. In seven of the cases, the contamination appears to be related to pre-existing conditions (based, for example, on evidence of upgradient ground-water contamination). At the eighth site, insufficient historical information was available and the contaminant found in the ground water (lead) was found to be inconsistent with those typically present in FBC wastes. EPA concluded from the review of these eight cases that contamination likely resulted from other sources; therefore, the observed damages do not result from FBC waste management. More detailed discussion of these eight sites are presented in the *Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Potential Damage Cases*, as well as in the CIBO report.

5.5 EXISTING REGULATIONS

EPA's objective in this analysis was to identify and evaluate the existing regulatory controls that pertain to the management of FBC wastes. The regulatory analysis is directed toward addressing the question of whether existing regulations adequately protect human health and the environment. The analysis also is helpful in understanding waste generation and current management practices.

The sections below discuss regulations addressing air pollution, water pollution, and solid and hazardous waste, respectively. Air regulations are relevant primarily because of their effect on waste generation. Water regulations have an influence both on waste generation and management, and, in particular, address the impact of FBC wastes on surface waters. Solid and hazardous waste regulations are of the greatest interest because they directly govern waste management practices.

The sections below describe federal regulations in each of these areas. In many cases, the implementation of these federal programs is carried out by the states. Therefore, where appropriate, aspects of state implementation also are discussed. Because the nuances of state implementation are of particular importance with respect to solid waste regulation, that section discusses state programs in detail. Where appropriate, that section also describes state control on two of the beneficial uses of concern to EPA: minefilling and soil amendment.

5.5.1 Regulations Addressing Air Pollution

The federal Clean Air Act (CAA) is intended to protect and enhance the quality of the nation's air resources. The CAA requirements most relevant to FBC wastes include the following:

- National Ambient Air Quality Standards (NAAQS) for particulate matter (PM)
- NAAQS for sulfur dioxide
- Title IV acid rain provisions
- NAAQS for ozone
- National Emissions Standards for Hazardous Air Pollutants (NESHAP).

Historically, CAA requirements have been a significant factor affecting the generation and collection of FBC wastes. Recent and forthcoming changes in these requirements also may impact waste generation or characteristics.

NAAQS for Particulate Matter

The NAAQS for PM establish maximum concentrations of PM with diameter less than or equal to 10 micrometers (PM10) in the ambient air. These standards are among the factors motivating the use of particulate control technologies at FFC facilities. EPA recently proposed to lower the size criterion to 2.5 micrometers, which may affect the volume of fly ash collected and selection of control technology; however, final standards will not be issued for at least 5 years, so the impacts of the new standard are difficult to predict at this time.

The NAAQS for PM are implemented through the following regulatory mechanisms: New Source Performance Standards and State Implementation Plans, described below.

New Source Performance Standards (NSPS). The NSPS subjects newly constructed or modified units to specific PM emissions limits. These limits may be met by changing fuel types, modifying combustion conditions, or installing control devices. The applicability of the NSPS and the specific limits imposed vary with the age and size of the combustion unit, with older and/or smaller units less likely to be subject to the NSPS. Specifically the regulation of facilities can be considered in four categories.

- 40 CFR 60 Subpart D governs the standards of performance for new fossil fuel-fired steam generators that were constructed or underwent major modification after August 17, 1971. Subpart D affects only units that are capable of burning fossil fuels at greater than 73 megawatts (MW) of heat input rate.

- Subpart Da affects utility units with the capacity to fire fuel at greater than 73 MW heat input rate that commenced production or major modification after September 18, 1978.

- Subpart Db affects coal-fired units with the capacity to fire fuel at greater than 29 MW of heat input rate that commenced construction or modification after June 19, 1984.

- Subpart Dc governs coal-fired units constructed or modified after June 9, 1989, with capacity to fire fuel at less than 29 MW but greater than 8.7 MW heat input rate.

With the exception of Subpart Da, which applies specifically to utilities, the NSPS requirements apply to all FBC units, utility or non-utility. Non-utilities, however, tend to have smaller capacities than utilities. Also, FBC units, in general, tend to be smaller and newer than conventional units. Therefore, FBC units, and particularly non-utility FBC units, are more likely captured by those NSPS requirements that apply to smaller capacity, newer units (i.e., Subparts Db and Dc). Note that under the NSPS regulations, facilities that were in operation before the dates stated in each of the four subparts are considered "grandfathered" and would not be subject to the newer standards unless they underwent a major modification.

State Implementation Plans (SIPs). The performance standards above can be enforced by a federal, state, or local regulatory agency. There are additional CAA regulations that could require an FBC unit to install a particulate removal device notwithstanding the grandfather clause in Subparts D, Da, Db, and Dc. SIPs may impose, on a state-by-state basis, PM controls of varying stringency on specific sources or categories of sources, including FBC facilities. Such controls are required under Title I of the CAA if a particular area is in nonattainment for the NAAQS for a criteria pollutant such as PM. For this reason, SIP controls will generally be more stringent in such nonattainment areas. In attainment areas, the prevention of significant deterioration (PSD) program requires new sources to apply Best Available Control Technology (BACT), which must be at least as stringent as NSPS.

NAAQS for Sulfur Dioxide and Title IV Acid Rain Requirements

Like the NAAQS for PM, the NAAQS for sulfur dioxide establish a maximum concentration of sulfur dioxide in the ambient air. The NAAQS for sulfur dioxide are implemented through NSPS and SIPs. The functioning and applicability of the sulfur dioxide NSPS requirements are similar to those for PM, although there is less variation based on age and size.

Each of the four categories of FBC facilities regulated under Subparts D, Da, Db, and Dc is subject to the same requirement: sulfur dioxide emissions must be less than 520 nanograms per joule (ng/J) of heat input. Facilities with greater than 22 MW of heat input capacity generally also must achieve a 10-percent reduction in their sulfur dioxide emissions, based on the potential concentration in fuel. An additional category of FBC units, those constructed or modified after June 9, 1989, and between 2.9 and 8.7 MW of heat input capacity, also must meet the 520 ng/J standard, but may do so based on certification from the fuel supplier that the sulfur content of the fuel is low enough to meet the standards. Finally, FBC units firing only waste coal are subject to a more stringent percent reduction requirement: a 20-percent reduction in their sulfur dioxide emissions, based on the potential concentration in fuel.

In addition to NSPS, states may impose controls through their SIPs to meet the sulfur dioxide NAAQS. These controls may vary in stringency depending on attainment status and may be placed on specific sources or categories of sources, including FBC units.

The Title IV acid rain provisions provide additional impetus for the application of FGD technology at utilities. These provisions require specific reductions of sulfur dioxide emissions via the following:

- Installing FGD equipment
- Switching to low sulfur fuel
- Purchasing emissions allowances from other sources that have exceeded their reduction requirements.

Affected sources are allowed complete flexibility in choosing among these options. The current phase of the Title IV program affects several hundred of the largest generating units at utilities. These requirements, therefore, do not currently apply to non-utility FBC units. EPA is currently evaluating further requirements for lower sulfur dioxide standards and emissions.

Because they capture sulfur oxides using a sorbent within the combustion bed, FBC units generally do not require the application of separate FGD technologies to comply with the Title IV acid rain provision or the NAAQS for sulfur dioxide. In fact, these regulations may have been a contributing factor in the development and commercialization of FBC technology.

NAAQS for Ozone

The NAAQS for ozone establish a maximum concentration of ozone in the ambient air. EPA recently lowered this concentration from 0.12 parts per million (ppm) to 0.08 ppm. The new standard allows four exceedences of the maximum in a region over a 3-year period. EPA expects states will meet the new standard by amending their SIPs to limit nitrogen oxide emissions at utilities. In proposing the new rule, EPA published a Regulatory Impact Analysis (RIA) forecasting changes in the operating practices of utilities that could result from these SIP modifications (EPA, 1997b). The RIA, however, did not specifically estimate the impact of these regulations on the subset of utilities utilizing FBC technology. Therefore, the impact on this segment is uncertain. The recent changes are not expected to affect non-utilities (and, in turn, non-utility FBC waste generation) significantly.

NESHAP

Under the NESHAP, EPA is required to establish technology-based standards for 189 hazardous air pollutants (HAPs). These standards are to be set on an industrial category basis and will apply to facilities (major sources) that emit greater than 10 tons/year of any one HAP or greater than 25 tons/year of any combination of HAPs.

EPA has studied HAP emissions from utility coal-fired steam generating units (including FBC units) and found that mercury from coal-fired utilities is the HAP of greatest concern. Dioxins and arsenic (primarily from coal-fired plants) also are of potential concern. EPA has deferred any determination as to whether regulations to control HAP emissions from utilities are appropriate and necessary (EPA, 1998c). If such regulations were promulgated, they could affect the characteristics or quantities of FFC solid wastes.

EPA has not studied HAP emissions specifically for non-utility FBC facilities. Because NESHAP will be set on an industrial category basis, when promulgated, the impact of these regulations on FFC waste generation and characteristics may vary depending on the industrial sector of the non-utility FBC facility.

5.5.2 Regulations Addressing Water Pollution

Under the federal Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) controls discharges to waters of the United States. The controls required under NPDES affect the collection and management of FBC wastes. In states authorized by EPA, these controls are implemented through state programs (often termed State Pollutant Discharge Elimination Systems, or SPDES). Because state programs must be at least as stringent as the federal program, the discussion here focuses on federal requirements as a lowest common denominator. NPDES requirements apply differently to two categories of discharges: process wastewaters and stormwater runoff. Neither the

NPDES process wastewater or NPDES stormwater requirements make a distinction between conventional and FBC units. Distinctions may apply, however, between utilities and non-utilities.

NPDES Requirements for Process Wastewaters

The NPDES requirements that apply to process wastewaters from utility FBC facilities are those for the steam electric point source category under 40 CFR Part 423. These requirements apply to facilities "primarily engaged in the generation of electricity for distribution and sale" (i.e., utilities). Non-utility FBC facilities face NPDES requirements for process wastewaters that are specific to their industrial sector. In most cases, under these requirements each discharge requires an individual NPDES permit with numeric limitations based on Best Practicable Control Technology Currently Available (BPT), Best Available Technology Economically Achievable (BAT), or New Source Performance Standards (NSPS). Facilities that discharge to publicly owned treatment works (POTWs) rather than directly to surface waters face Pretreatment Standards for Existing Sources (PSES) similar to BAT, or Pretreatment Standards for New Sources (PSNS) similar to NSPS.

As discussed in Section 5.3, FBC wastes are rarely managed wet. Therefore, the NPDES process wastewater requirements generally are not relevant to management of these wastes. In those unusual cases where FBC wastes are managed wet, the most relevant requirements are total suspended solids (TSS) limits.

At non-utilities, the specific NPDES effluent standards applied depend on industrial category. Effluent standards with potential applicability to non-utility FBC facilities include those for the following industry categories:

- Pulp, paper, and paperboard (40 CFR Part 430)
- Organic chemicals, plastics, and synthetic fibers (40 CFR Part 414)
- Inorganic chemicals manufacturing (40 CFR Part 415)
- Grain mills (40 CFR Part 406).

The standards for all of these categories include TSS limits, and these limits are applicable to nearly all of the industrial subcategories covered under each category. Some subcategories are subject to zero discharge requirements. Some FBC facilities are found in other industrial categories, many of which are also subject to TSS limits. Some facilities (such as education institutions) may not be subject to the specific standards of any industrial category. In these cases, the specific effluent limitations would be determined on a case-by-case basis as part of the individual NPDES permit for the facility.

At utilities, the steam electric category NPDES requirements place TSS limits directly on fly ash handling and bottom ash handling waters. In addition, the NSPS for the steam electric category include a zero discharge requirement for fly ash handling water. These steam electric requirements also may be incorporated in individual permits at non-utilities to supplement their industrial category requirements. Application of steam electric requirements to relevant waste streams at non-utility fossil fuel combustors is left to the best professional judgment of the individual permit writer (EPA, 1996).

In the few cases in which FBC wastes are managed wet, the TSS and zero discharge requirements discussed above are relevant as follows. Facilities may have to settle or otherwise remove a certain amount of waste solids from the handling water to meet the TSS limits prior to discharge. Zero discharge requirements effectively eliminate the release of waste solids to surface water. The requirements control the direct release of fly ash, bed ash, and any treatment solids to surface waters.

NPDES Requirements for Stormwater

NPDES stormwater requirements apply to stormwater runoff from FFC facilities, which may include runoff from operating areas, ash handling areas, and waste management units. Like the process wastewater requirements, stormwater requirements have been established on an industrial sector basis. The NPDES stormwater requirements, however, are additive across industrial sectors. Therefore, the steam electric requirements apply to both utility and non-utility FBC facilities. A chemical manufacturer, for example, operating an FBC unit must meet both chemical manufacturing and steam electric stormwater requirements.

Facilities can meet the stormwater requirements by including stormwater in their individual NPDES permit or seeking coverage under a general permit by submitting a Notice of Intent (NOI). Individual permit control and monitoring requirements will be facility-specific, subject to the judgment of the permit writer.

When covered by a general stormwater permit, requirements include implementation of a stormwater pollution prevention plan, “reasonable and appropriate” control measures, and 1 or 2 years of monitoring and reporting. No site visit by regulators is required under the general permit. Under the general permit approach, facilities have a great deal of flexibility in selecting appropriate control measures for runoff that may have contacted FBC wastes. The general permit requirements include recommended best management practices for stormwater at steam electric facilities, landfills, treatment works, and construction areas greater than 5 acres. Because these requirements are additive across industrial sectors, if the hypothetical chemical manufacturer described above also operated an onsite ash landfill, that facility would have to meet landfill requirements in addition to chemical manufacturing and steam electric requirements.

Because the stormwater program is relatively new and managed by authorized states, the number of facilities with general versus individual permits is not known. EPA handles NOIs for 10 nonauthorized states. In these states, 700 steam electric facilities (utilities and non-utilities) have filed for general permits.

5.5.3 Regulations Addressing Solid and Hazardous Waste

Subtitle C of RCRA establishes a “cradle-to-grave” management system for wastes that are considered hazardous because they fail tests based on physical and chemical characteristics (i.e., toxicity, corrosivity, ignitability, and reactivity) or because they are listed as hazardous by EPA. Federal regulations establish stringent environmental and administrative controls that must be applied to management of these wastes. FBC wastes are currently exempt from federal regulation as hazardous waste under Subtitle C pending this Report to Congress and the subsequent regulatory determination. Therefore, these wastes are subject to the requirements of Subtitle D of RCRA as nonhazardous solid waste.

Implementation of Subtitle D is the responsibility of individual states, but nothing prevents states from imposing more stringent requirements (including hazardous waste requirements) on FBC wastes. FBC units are located in 30 of the 50 states. EPA characterized the waste management requirements in

27 of these 30 states using survey and other data sources.[5] All of these states regulate FBC wastes under the same programs as CCWs from conventional combustion processes.

Currently, 24 of the 27 states for which data are available (representing 86 percent of the surveyed FBC generating capacity and 78 percent of FBC capacity overall) duplicate the federal policy exempting CCWs (including those from coal-fired FBC) from hazardous waste regulations. The three remaining states (Washington, Maine, and California) do not exempt FBC wastes from state hazardous waste regulation. In these states, any FBC wastes that fail the hazardous waste characteristic tests would be subject to state hazardous waste requirements and managed in units that meet permitting, design, operating, corrective action, and closure standards.

As discussed in Section 5.2, FBC wastes seldom fail the hazardous waste characteristic tests. Therefore, the majority of FBC wastes would be subject to state requirements under Subtitle D because they do not fail the hazardous waste characteristic tests and/or are generated in the states that duplicate the federal exemption. Table 5-10 describes state regulatory authority with respect to FBC landfills in the 27 states for which data are available. These data show that the majority of states have the authority to require permits and to impose physical controls and monitoring requirements on FBC landfills, at least on a case-by-case basis. The types of regulatory controls include siting controls, liners, leachate collection systems, ground-water monitoring, closure controls, daily (or other operational) cover, and fugitive dust controls. EPA believes that the use of such controls has the potential to mitigate risks, particularly ground-water pathway risks, from FBC waste disposal. The adequacy of this mitigation depends on the extent to which states are exercising their authority in situations in which climate, geology, site-specific conditions, and waste characteristics affect the magnitude of the risk.

Section 5.3 of this report found that most of the FBC waste landfills surveyed are subject to regulatory permits and ground-water monitoring requirements and nearly all incorporate dust suppression and run-on or runoff controls. Just over half of those surveyed have covers and leachate collection systems and just under half are lined. These statistics suggest that states have exercised their authority to impose control at FBC waste management units. To further examine state implementation of solid waste requirements on FBC wastes, EPA examined in greater detail the regulations applicable in two states: Pennsylvania and California. These two states are ranked first and second in FBC generating capacity. Together, they account for more than 30 percent of total U.S. FBC electrical generation capacity. Table 5-11 summarizes the requirements in these states. Because surface impoundments are seldom used for FBC wastes, this analysis focuses on landfill regulations.

Examination of these two states reveals some variation in approaches to implementing Subtitle D requirements for FBC landfills. Both Pennsylvania and California subject FBC wastes to regulations that impose requirements tailored to the characteristics of the waste. The program in California, however, contains special provisions that apply to nonhazardous FBC wastes. The state allows generators of FBC wastes that do not test hazardous to utilize facilities in the “standardized” regulatory tier. Nonhazardous FBC wastes disposed in these facilities are subject to less stringent requirements, regardless of their characteristics.

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[5] Four states (Colorado, Florida, Georgia, and Pennsylvania) indicated in the CIBO survey that they impose different requirements based on the combustion technology used. EPA supplemented the survey data with specific information from its review of regulations in Pennsylvania. EPA did not collect specific data on FBC waste requirements in the other three states. These three states account for less than 10 percent of FBC equivalent electrical generating capacity.

Table 5-10. Current State Regulatory Controls on FBC Landfills

	Number of States[a]	Percent of States[b]	Percent of Capacity[c]
Permit Onsite	23	85%	94%
Permit Offsite	27	100%	100%
Siting Controls	25	93%	96%
Liner	23	85%	91%
Leachate Collection Systems	23	85%	95%
Ground-Water Monitoring	25	93%	97%
Closure Controls	25	93%	94%
Cover and/or Dust Controls	27	100%	100%
Corrective Action	22	81%	96%

[a] Number of states with authority to impose the indicated requirement, either by regulation or on a case-by-case basis.
[b] Percent of the 27 surveyed states with authority. For testing requirements, percent of 17 states providing information on these requirements.
[c] Percent of FBC generating capacity in the 27 surveyed states represented by states with authority.
Sources: CIBO, 1997c; EPA, 1995b; ASTSWMO, 1995; ACAA, 1996a

Table 5-11. State Waste Management Requirements Applicable to FBC Wastes in Selected States

Pennsylvania	
Landfill Requirements	Landfills are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the landfill. Based on available characterization data, most FBC wastes would be amenable to Class III landfills. Requirements for these include siting restrictions, a 4-foot attenuating soil base (or 1-foot-per-4 feet of waste), fugitive dust control, daily cover, soil erosion control, ground-water monitoring, 2-foot clay cap at closure, and revegetation at closure.
Grandfather Clause	Units permitted prior to July 4, 1992, were required to modify their operations to comply with the above requirements by July 4, 1997. Liner and leachate collection requirements may be modified if the operator could demonstrate that the unit had not caused unacceptable ground-water degradation.
Minefill Requirements	FBC wastes must meet TCLP limits for disposal at a Class III landfill. Ground-water monitoring is required.
Soil Amendment Requirements	FBC wastes must meet pH limits. State agency notification and runoff and erosion controls are required. There are siting limitations.
California	
Landfill Requirements	Any FBC wastes failing hazardous waste characteristic tests are subject to state hazardous waste management requirements. However, based on available characterization data, most FBC wastes would be managed under the non-hazardous solid waste program. Under this program, FBC wastes may be managed in special “nonhazardous ash disposal/monofill facilities” which fall into the state’s “standardized” regulatory tier. FBC wastes also may be managed in solid waste landfills in the more stringently regulated “full permit” tier. “Nonhazardous ash disposal/monofill facilities” tier are required to obtain a standardized permit and are subject to minimum operating standards including siting restrictions, control of windblown material, and drainage control.

Grandfather Clause	Information not available.
Minefill Requirements	Information not available.
Soil Amendment Requirements	Information not available.

5.6 WASTE MANAGEMENT ALTERNATIVES

The risk assessment identified potential ground-water pathway risks to human health from FBC wastes managed in unlined landfills. Mitigation of these potential risks might be accomplished through the use of technologies that prevent or contain and collect leachate from FBC landfills. Specifically, EPA identified the technologies in Table 5-12 as an alternative that would be practical and effective to target and mitigate the potential ground-water risk. The technologies shown in Table 5-12 are considered further in the cost and economic impact analysis (Section 5.7). Section 5.7 includes the option of sending waste to an offsite commercial landfill employing these technologies, as well as the option of constructing such a unit on site. Note that these technologies are consistent with those required under Subtitle D of RCRA.

Table 5-12. Management Alternatives for Non-Utility CCW

Landfill
Design includes filter fabric, 1' sand layer, 2' clay liner, synthetic high-density polyethelene (HDPE) liner, leachate collection system, and ground-water wells. Operation includes environmental monitoring and leachate collection and treatment. Closure requirements include 6" topsoil and vegetation, filter fabric, 1.5' sand layer, 2' clay layer, synthetic (HDPE) liner, and a cover drainage system. Post-closure includes environmental monitoring, landscape maintenance, slope maintenance, inspection, and administration.

Of the beneficial uses discussed in Section 5.3.5, agricultural use may be of environmental concern, based on the non-ground-water risk assessment that found potential arsenic risks to human health from this practice. An approach for mitigating this potential risk might include a standard limiting the arsenic concentration in wastes intended for this use. The cost estimate for FBC waste includes consideration of a more stringent approach: a ban on agricultural use. Minefilling also may be of concern, particularly when wastes are placed below the water table. EPA is seeking further information on this practice.

5.7 COMPLIANCE COSTS AND ECONOMIC IMPACTS

This section discusses the costs and economic impacts of risk mitigation alternatives for FBC wastes. Details of this analysis are documented as part of the EPA docket.

5.7.1 Overview and Methodology

In estimating costs and economic impacts for FBC facilities, EPA used a similar approach to that described in Section 3.7.1. Salient distinctions between the analysis in Section 3.7 and this analysis are reviewed below.

EPA's analysis for FBC facilities began with 84 FBC facilities identified in the CIBO FBC Report (CIBO, 1997c). Half of these are in the electric service sector. EPA estimated the incremental compliance cost of the risk mitigation alternative described in Section 5.6. As described in that section, this requires generators to construct onsite composite-lined landfills or transport waste to an offsite commercial Subtitle D landfill. The more economical method was assigned to each plant depending upon its estimated annual FBC waste generation rate.

The cost estimate summed costs in five categories: initial capital costs, recurring capital costs, annual operating and maintenance costs, closure costs, and annual post-closure costs. The specific components included in each cost category were the same as those in the analysis for coal-fired utility comanaged waste (see Section 3.7.1). As in that analysis, the cost estimate for FBC facilities employed three different landfill sizes. Table 5-13 identifies the design features for FBC landfills.

Table 5-13. Design Parameters Assumed for Small, Medium, and Large FBC Landfills

Parameter		Landfill
Sizes (tons/year)	small	5,000
	medium	50,000
	large	500,000
Depth (feet)		Pile design
	small	1.0
	medium	1.0
	large	3.0
		Combination fill design
	small	17.1
	medium	51.8
	large	75.1
Height (feet)		Pile design
	small	25.0
	medium	25.0
	large	84.9
		Combination fill design
	small	21.4
	medium	20.3
	large	74.6
Area (acres)		Pile design
	small	7.3
	medium	106.6
	large	207.2
		Combination fill design
	small	4.6
	medium	24.5
	large	111.8

Note: Landfill designs considered include a "pile design" constructed primarily above grade and a "combination fill design" constructed both above and below grade.

For FBC wastes, the cost estimate was based on alternative management for the quantity of FBC wastes currently disposed in landfills that do not meet the requirements described in Section 5.6. EPA also estimated the additional, incremental cost if the large quantity of FBC waste currently minefilled and used in agriculture also were subject to the alternative management practices. This latter cost would reflect a ban on minefilling and agricultural use. This is discussed below.

As in the analysis for coal-fired utility comanaged waste, a single cost equation was developed, annualized costs were estimated as a function of facility-specific waste generation, and total industry costs were derived by summing the facility-specific estimates. Costs and economic impacts are set forth in the following three sections: incremental compliance cost, compliance cost impact on facilities as a function of size, and industry impact.

Incremental compliance costs are the costs of risk mitigation practices *over and above* the cost of current management practices. Using incremental compliance costs as an indicator of potential cost burden, the analysis examined impacts on individual facilities as a function of size. As in Section 3.7, this was performed using pro forma financial statements for three representative plant sizes. As for the conventional coal-fired utility sector, the use of econometric models for the industry impact evaluation was considered and rejected because of the uncertainty surrounding ongoing deregulation of the electric power industry and the diversity of industrial and institutional sectors potentially affected. The industry-level analysis, therefore, focuses on the number of affected facilities and the magnitude of incremental compliance costs relative to the value of electricity sales.

5.7.2 Incremental Compliance Cost

EPA's estimate of the incremental compliance cost for FBC facilities is approximately $32 million per year. If the quantities of FBC waste currently used in minefill and agricultural applications were subject instead to the risk mitigation alternative of Section 5.6, the additional incremental compliance cost would be an estimated $52 million per year (for a total of some $84 million per year). As discussed above, this latter cost would reflect a ban on minefilling and agricultural use. Variations on this approach, as noted, could substantially reduce the total incremental compliance cost with approximately $32 million being the floor. A limit on the arsenic concentration in FBC wastes destined for agricultural use, for example, would affect a smaller quantity of waste than a ban on agricultural use. Although the quantity of waste in agricultural use is small relative to quantities used in minefilling, this variation would still result in a decrease in compliance costs.

Costs, again, are incremental (above current costs). Annual costs were discounted at 7 percent to 1998 dollars, with no inflation built into out-year estimates. Also, it was presumed that compliance would be required immediately, and that amortization would take place over 40 years. As with the utility and non-utility sectors, delayed compliance, were this to be considered, would result in much reduced costs.

5.7.3 Compliance Cost Impact on Facilities as a Function of Size

EPA believes that the ability of industry to pass through cost increases will be limited because only a small share of plants within the affected industries operate FBC units. Competition from unaffected facilities would restrict the ability of facilities facing incremental compliance costs to increase prices. Therefore, this analysis includes no analytical consideration of price effects.

Also, the analysis below *excludes* costs for quantities currently used in mining and agriculture. The minefilling issue is discussed in detail in Section 3. If minefilling were to be banned, the impacts shown below would increase roughly in proportion to the compliance costs given in Section 5.7.2.

As discussed previously in this chapter, about half of the 84 FBC facilities are operated/owned by entities in the electric service industry (i.e., independent power producers and utilities). The remaining FBC waste generating facilities include about 7 operated by universities or colleges, about 15 operated by large businesses such as Archer Daniels Midland, General Motors, Iowa Beef Processors, Exxon, and Fort Howard Paper, and the balance—about 20—operated by various small businesses or unknown operators. Thus, EPA addressed the electric power segment of FBC facilities separately from the more broad-based industrial/institutional FBC facilities.

Electric Power Sector

Based on the incremental compliance cost estimate, 42 FBC waste generators in the electric power industry would incur incremental compliance costs of about $15.2 million per year, or about $361,000 per facility. Economic impacts at the plant level will depend on several major factors, including quantity of fuel used, quality of fuel, profitability, and production technology. To assess these impacts across the range of plants, EPA estimated financial data for model plants representing three size ranges: large (generating capacity of 100 MW), medium (generating capacity of 50 MW), and small (generating capacity of 30 MW). These model facilities are representative of independent power producers. Table 5-14 compares incremental compliance costs to revenues and net income for these three model plants.

Table 5-14. Plant-Level Impact of Incremental Compliance Costs

	Large FBC Independent Power Producer		Medium FBC Independent Power Producer		Small FBC Independent Power Producer	
	$1,000's	Percent of Revenues	$1,000's	Percent of Revenues	$1,000's	Percent of Revenues
Revenues from Electricity	37,840	100%	18,900	100%	11,400	100%
Baseline Before Tax Net Income	3,780	***10.0%***	1,510	***8.0%***	790	***7.0%***
Expected Incremental Compliance Costs (replace unlined management unit with composite-lined unit)	520	1.4%	280	1.5%	190	1.7%
Expected Post-Compliance Net Income	3,260	***8.6%***	1,230	***6.5%***	600	***5.3%***

The incremental compliance cost for FBC waste should not impact the financial viability of FBC facilities in the electric service sector. This appears true even for plants transitioning from the worst case unlined landfill to a composite-lined landfill. For example, a large FBC independent power plant with 100 MW of generating capacity is estimated to comply for about $520,000 per year (or about $13 per ton of waste). Based on typical annual revenues and cost, compliance costs would increase overall costs by 1.4 percent of revenues. Without any price adjustments, net income before taxes for a typical FBC facility would be reduced from about 10 percent to 8.6 percent and remain at nearly $3.3 million per year. EPA recognizes that such profit margin reductions may be considered significant by the individual firm.

Financial impacts on a medium-sized FBC independent power plant suggest it should also remain financially viable. Costs would increase by about 1.5 percent of revenues, with profitability (before tax) at 6.5 percent of revenue and net income levels after compliance of more than $1.2 million per year. (Annual incremental compliance costs are estimated at $14 per ton of FBC waste, or about $280,000 per year.) Small FBC independent power plants would incur slightly higher impacts at about 1.7 percent of revenues.

Industrial/Institutional Sectors

As for conventional non-utility combustors, industrial and institutional FBC facilities include a wide variety of facilities that generate electricity or energy for primarily internal use. The vast majority of firms in these sectors, however, do not operate FBC units or burn coal at all. Because of the smaller number of affected FBC facilities, FBC facilities represent an even smaller share of the corresponding industry sectors than do conventional non-utility combustors. As for conventional non-utilities, fossil fuel use and costs are a relatively small part of production inputs and costs. Therefore, the conclusions presented in the paragraph above generally also are applicable to industrial and institutional FBC facilities.

5.7.4 Industry Impacts

This analysis addresses the overall industry and the general implications for market supply of selected industries.

Approximately half of all FBC facilities, as noted, are in the electric generating sector. Department of Energy data show that independent power producers as a group generated 61.4 billion kWh from coal fired generating capacity. Assuming this output is valued at $0.07 per kWh, the equivalent market value of this output would be $4.3 billion. Assuming all FBC electric power facilities fall in this special power generating segment, incremental compliance costs would equal about 0.3 percent of the segment's general market value, as shown in Table 5-15.

Table 5-15. Industry-Level Economic Impacts (FBC Wastes)

Sector	Industry Sales ($ billion/yr)	Incremental Compliance Cost ($ billion/yr)	Compliance Cost as a Percentage of Sales
FBC Independent Power	$4.3	$0.015	0.3%
FBC Industrial/Institutional	Not estimated *	$0.017	*
* Given the similar variety of sectors and smaller number of facilities, impacts are expected to be similar to or less significant than those for conventional non-utilities (see Section 4.7.4).			

Institutional/industrial FBC facilities include a broad variety of industry sectors similar to that reflected in the conventional non-utility combustion population. Because of their small numbers, FBC facilities account for an even smaller share of these industry sectors. Thus, the industry-wide economic impacts from industrial and institutional FBC facilities are expected to be similar to or less significant than those presented in Section 4.7.4.

5.8 FINDINGS AND RECOMMENDATIONS

5.8.1 Introduction

Based on the information collected for this Report to Congress, this section presents a summary of the Agency's main findings presented under headings that parallel the organization of this chapter. It then presents the Agency's tentative conclusions concerning the disposal and beneficial uses of FBC wastes as discussed in this chapter.

5.8.2 Findings

Sector Profile

- There are about 84 facilities with a total of 123 FBC boilers in the United States. The facilities are distributed throughout the United States, but Pennsylvania and California together have 29 facilities.

- Commercial-scale FBC technology is relatively new in the United States. Its use has increased during the past 20 years, and the trend appears to be continuing.

- The advantages of FBC over conventional processes include flexibility in fuel grades, combustion efficiency, and emissions control.

Waste Generation and Characteristics

- Nearly 10-million tons of combustion wastes are generated annually by FBC units. The wastes comprise mostly fly ash and bottom ash (called bed ash).

- These wastes contain relatively high residual levels of lime (which is introduced with fuel to control sulfur emissions) and often exhibit self-cementing properties.

- The types of low-volume wastes generated by FBC operations are similar to those generated at facilities that use conventional boiler technologies, such as pulverized coal boilers commonly used at utility facilities. Based on limited available data, the characteristics of FBC low-volume wastes are also similar to the counterpart utility low volume wastes at facilities that employ conventional boiler technologies.

- The constituents of concern in the combustion wastes are trace metal elements, in particular the eight RCRA metals. No organic constituents and no radionuclides were identified at potential levels of concern in these wastes.

- FBC wastes seldom test characteristically hazardous. Only one constituent, mercury, in one sample at one facility (out of 24 facilities for which data are available) exceeded the regulatory level.

- Based on limited data, none of the combustion wastes appears to be characteristically corrosive, reactive, or ignitable.

Waste Management Practices

- The predominant FBC waste disposal practice is placement in landfills. The typical landfill is about 40 acres in size. Surface impoundments are rarely used to manage these wastes. These wastes are monofilled and to a lesser extent are comanaged with low-volume wastes and/or other industrial wastes.

- The current trend for environmental controls at FBC waste management units is toward use of liners, cover, leachate collection, dust suppression, and surface and ground-water monitoring.

- A significant portion of FBC wastes is reused. About 75 percent of the wastes are currently managed through beneficial uses. The largest single beneficial use is in minefill, including mine reclamation, which accounts for about 60 percent of the generated wastes. Other beneficial uses include waste stabilization (6 percent), construction fill (5 percent), and agricultural use (1 percent).

Potential Risks and Damage Cases

- EPA conducted a risk assessment that found a lack of potential human health risk for virtually all waste constituents. Arsenic was the one constituent for which the Agency identified potential human health risks via the ground-water pathway for FBC wastes that are managed in unlined landfills. The identified risk is based on high-end risk scenarios in EPA's risk modeling analysis for human ingestion of well water influenced by releases from the waste management unit. The time to reach significant risk in ground water is estimated to be in excess of 3,000 years.

- EPA conducted a risk assessment that found a lack of potential human health risk for virtually all waste constituents. Arsenic was the one constituent for which the Agency identified potential human health risks via non-ground-water pathways where these wastes are used as soil amendments for agricultural purposes. The identified risk is based on high-end risk scenarios in EPA's risk modeling analysis, for human ingestion exposure routes.

- The Agency did not perform a risk analysis for management in impoundments because they are rarely used and the known impoundments are lined; however, the Agency believes that there should be no significant ground-water risks posed by lined waste management units.

- The Agency identified no ecological risks associated with management of FBC wastes.

- The Agency identified no documented damage cases associated with the management of FBC wastes.

- Some natural arsenic levels in U.S. soils have the potential to pose higher risks than the risk identified with the level of arsenic contributed by these wastes for non-ground-water pathways.

Existing Regulatory Controls, State, and Federal Requirements

- The FBC sector has a significant level of installed environmental controls for these wastes. Most of the active FBC waste landfills are subject to regulatory permits and ground-water monitoring requirements; nearly all incorporate dust suppression and surface runon/runoff controls. Nearly half are lined and have leachate collection systems and covers.

- States increasingly have begun to impose controls on FBC waste management units. In addition to regulatory permit programs, the majority of states now have the authority to require siting controls, liners, leachate collection systems, ground-water monitoring, closure controls, daily or other operational cover, and fugitive dust controls for management of these wastes.

Potential Costs and Impacts of Regulation

- The Agency estimates that the total annual incremental compliance costs for mitigation of the potential arsenic risks identified in this study would be approximately $32 million (1998$). These costs represent replacement of existing unlined management units with lined management units, and implementing ground-water monitoring and leachate collection and treatment. These measures do not represent implementation of full Subtitle C requirements, but rather modifications of such requirements that could potentially be adopted under Section 3004(x) of RCRA.

- If these wastes were to be regulated under full Subtitle C, virtually all existing facilities would be required to invest substantial funds and resources to modify existing management practices. The total annual cost of full Subtitle C requirements would considerably exceed the $32 million (1998 $) estimate above.

- If beneficial uses of theses wastes were subject to Subtitle C requirements, possibly all beneficial use practices and markets would cease. If so, the impact on waste management practices would be substantial, considering that about 75 percent of FBC wastes are reused.

5.8.3 Recommendations

Following are the Agency's recommendations for the wastes covered in this chapter. The recommendations are based on EPA's analysis of the eight Congressionally mandated study factors (Section 1.2). These conclusions are subject to change based on continuing information collection, continuing consultations with other government agencies and the Congress, and comments and new information submitted to EPA during the comment period and any public hearings on this report. The final Agency decision on the appropriate regulatory status for these wastes will be issued after receipt and consideration of comments as part of the Regulatory Determination, which will be issued within 6 months.

1. *The Agency has tentatively concluded that disposal of these wastes should remain exempt from RCRA Subtitle C.*

As with the utility and non-utility coal combustion wastes addressed in Chapters 3 and 4, the Agency has tentatively concluded that FBC wastes, including wastes from petroleum coke combustion and from other fuels that are co-fired with coal, and also low-volume wastes where they are managed with the combustion wastes, generally present a low inherent toxicity, are seldom characteristically hazardous, and generally do not present a risk to human health and the environment. State programs increasingly require more sophisticated environmental controls at these types of facilities. For example, most all of the FBC landfills are subject to regulatory permits and ground-water monitoring requirements; nearly all implement dust suppression and runon/runoff controls. No documented damage cases were identified and no significant ecological risks were identified. These types of facilities are typically located in areas of low population and thus present infrequent opportunity for human exposure. Although arsenic was identified from EPA modeling to pose a potential risk at unlined landfills, there were no documented problem or damage cases identified with arsenic as a constituent of concern. The predominant practice is to manage these wastes in landfills, with a much lower frequency of using impoundments. Nearly half of the landfills are lined and more than half have leachate collection systems and covers. Overall, the Agency believes that regulation under Subtitle C authority is not warranted when these wastes are disposed. For the issues discussed below involving agricultural use and management of these wastes in mines (minefill), the Agency is still considering whether some regulation under RCRA Subtitle C may be warranted.

2. *The Agency has tentatively concluded that most beneficial uses of these wastes should remain exempt from Subtitle C.*

No significant risks to human health and the environment were identified or believed to exist for any beneficial uses of these wastes, with the possible exception of minefill and agricultural use as discussed below. This is based on one or more of the following reasons for each use or resulting product: absence of identifiable damage cases, fixation of the waste in finished products which immobilizes the material, and/or low probability of human exposure to the material.

3. The Agency is tentatively considering the option of subjecting practices involving the use of these wastes for agricultural purposes (i.e., as a soil nutrient supplement or other amendment) to some form of regulation under Subtitle C.

As mentioned above, the Agency identified potential risk from exposure to arsenic in these wastes when they are used for agricultural purposes. The risks identified with this practice may be of sufficient concern to consider whether some form of control under Subtitle C is appropriate, given the increasing trend for use of these materials as agricultural amendments. An example of such controls could include regulation of the content of these materials such that arsenic concentrations could be no higher than that found in agricultural lime. On the other hand, imposition of controls under Subtitle C may not be warranted if sufficient protection may be afforded by the Agency engaging the industry to establish voluntary controls on this practice. An example of such voluntary controls could consist of an agreement to limit the level of arsenic in these materials. The Agency solicits comment on its tentative conclusion and specific approaches that could be pursued to address the concern..

A significant amount of FBC waste, about 60 percent, is used for minefill. Of this amount, large quantities are used specifically for reclamation of old surface coal mine working. EPA recognizes that mine reclamation practices with the highly alkaline FBC wastes can have some significant, positive environmental benefits. For example, the FBC wastes contribute to neutralizing acid mine drainage at the old mine workings, and when mine reclamation activities are completed, new productive uses may be made of the land. The Agency also realizes that there are a number of well-managed state mine reclamation programs that oversee the application of FBC wastes. RCRA, however, does require the Agency to review the management of these wastes. As discussed in Chapter 3's recommendations, the potential for risks associated with this practice may be of sufficient concern to consider whether some form of control under Subtitle C is appropriate, given the increasing trend for use of these materials as minefill. The Agency, however, currently lacks sufficient information with which to adequately assess risk associated with this practice and therefore to decide whether this practice should remain exempt from Subtitle C. The Agency solicits comment on whether there are some minefill practices that are universally poor and warrant specific attention. For example, the Agency has found several situations in which cement kiln dust placed in direct contact with the ground-water table has created problems. EPA also seeks comment on whether coal or other fossil fuel combustion wastes used as minefill and placed in direct contact with the water table would create environmental concerns, and if that specific practice should be regulated. The Agency’s focus is on potential risks that may be posed via the ground-water and surface pathways from use of these wastes as minefill.

6.0 OIL COMBUSTION WASTES

Oil combustion is used by utilities to generate electricity and by non-utilities to generate electricity, heat, or steam for a variety of operations. The analysis of oil-fired combustion processes and wastes in this report is based primarily on electric utility data. EPA has included available characterization information and analysis of non-utility operations in this study. Only a portion of the oil combustion facility population generates significant amounts of combustion waste. This portion comprises steam electric plants that burn residual fuel oil and is described further in Section 6.1.

SECTOR OVERVIEW

Petroleum products account for a substantial portion of the energy consumed in the United States—nearly 40 percent in 1997 according to the Energy Information Administration (EIA, 1998a). Most of this, however, is in the form of motor gasoline and other fuels used in the transportation sector. Only a fraction of U.S. petroleum consumption is by utilities and non-utility combustors, and only part of this is residual fuel oil, which is the only form likely to generate significant quantities of combustion waste (EIA, 1998a).

In the utility sector, the total amount of electricity generated by oil is small relative to the total generation of electricity. Electricity from oil combustion is less than 3 percent of a total that includes hydroelectric and nuclear as well as fossil fuel combustion (FFC) (EIA, 1998a). As discussed in Chapter 2, oil combustors represent a much smaller portion of utility FFC capacity than coal combustors. Oil combustion is, however, the dominant utility power source for certain regions of the United States (e.g., Florida, Hawaii, the Northeast) and the territories (Puerto Rico, the Virgin Islands, and Guam).

Additionally, oil has a history of use in support of utilities that burn coal for their baseload but use oil units to meet peak needs. These peakload units are used to supply electricity during periods of high electricity demand. The predominant characteristic of the peaking unit is the ability to startup and shutdown relatively rapidly, a characteristic that coal-fired units are unable to provide, but to which oil and gas are well-suited. Oil also may be used in coal-fired boilers for startup and flame stabilization. This practice, however, was covered by the 1993 Regulatory Detemrination.

As of December 1994, there were 177 utility facilities in the United States and its territories that combusted oil (EEI, 1994). Some of these facilities burned only oil, some operated both oil-fired boilers and boilers fired by other fossil fuels, and other facilities used oil as alternate fuel in units that primarily burned other fossil fuels. Figure 6-1 shows the geographic distribution of these facilities. Only 40 of these facilities are baseload oil-fired generators. Because of this, the location of facilities shown in the figure does not closely mirror the concentration of oil-fired utility capacity in the United States.

In fact, the concentration of oil-fired utility capacity corresponds more closely to the presence of large, oil-fired baseload units in certain regions of the country. Table 6-1 shows the location of these baseload units. It is these baseload units that are likely to generate significant quantities of oil combustion waste on a regular basis. Thus, while utility oil combustion waste has the potential to be generated in a number of locations, generation and management of significant quantities of this waste takes place primarily in the Northeast, mid-Atlantic, and Florida.

Figure 6-1. Number of Utility Power Plants Burning Oil (in whole or in part) by State

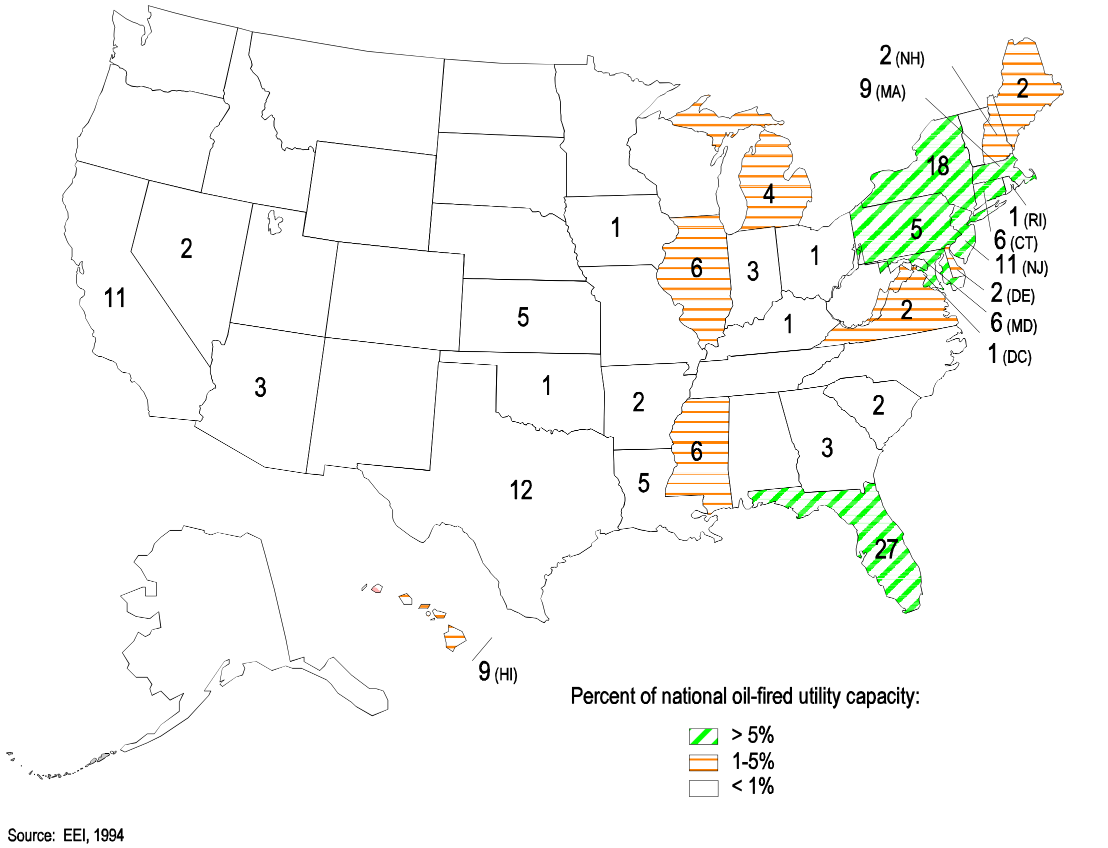


Table 6-1. Locations of Utilities with Oil-Fired Baseload Units

Location	Number of Facilities
Florida	11
Islands (GU, HI, PR, VI)	13
New England (MA, ME, CT)	6
Mid-Atlantic (NY, NJ, MD, DE)	10
Total	**40**
Source: EEI, 1994	

Oil-fired non-utilities represent a much larger number of facilities than do utilities. The 1990 U.S. EPA National Interim Emissions Inventory (EPA, 1990) includes more than 2,000 facilities with oil-fired units.[1] These facilities, however, account for only about 25 percent more generating capacity than

[1] As discussed in Chapter 4, because the 1990 National Interim Emissions Inventory captures only the largest non-utilities, it likely underestimates the total number of non-utility fossil fuel combustors. The small facilities that are not included in the database, however, are unlikely to generate significant quantities of waste.

oil-fired utilities. Equivalent electrical generating capacity is approximately 54,000 megawatts (MW) for oil-fired non-utilities (EPA, 1990) compared to 43,000 MW for oil-fired utilities (EEI, 1994). Unlike utilities, oil-fired non-utilities are distributed throughout the United States and in a variety of settings (urban to rural). As discussed in Section 6.1, the fuel and air pollution control technology characteristics of non-utilities indicate they are a less significant source of oil combustion waste than are utilities.

Despite its significance within certain niches (i.e., regional power generation, peakload units, non-utility use), the quantity of oil used to generate power is decreasing. The last 20 years have seen a significant drop in the use of fuel oil by utilities, from over 600-million barrels (25.2-billion gallons) in 1978 to only 86-million barrels (3.6-billion gallons) in 1995 with the steepest decline between 1978 to 1985 (EPRI, 1998a). This trend corresponds to a decline in construction of new oil-fired utility plants. While over 100 units were constructed during the 1960s and 1970s, the Electric Power Research Institute (EPRI) reports that only three new units have been brought on line since 1980. EPRI additionally reports that many oil units have been, or are being, converted to burn both natural gas and oil to provide additional flexibility in economical fuel choice (EPRI, 1998a).

As discussed in Chapter 2, the declining trend for oil combustion is expected to continue during the next two decades. Oil-fired utility steam plants are expected to be replaced by combustion turbine technologies. As a result, while industrial combustion of residual oil is expected to grow modestly, this growth will be more than counter balanced by a dramatic reduction for oil-fired utilities (EIA, 1998a).

6.1 WASTE GENERATION

The generation of large-volume wastes from oil combustion depends on combustion technologies (Section 6.1.1), air pollution control technologies (Section 6.1.2), and fuel type (Section 6.1.3). Oil combustion wastes (OCWs) consist primarily of the following:

- **Fly ash.** The fine particles entrained in the flue gas leaving the boiler. If present, a particulate control system will capture some part of these particles. Additionally, particles may adhere to equipment through which the flue gas is routed (e.g., the air preheater) or be knocked down in other units (e.g., the economizer). These particles are removed during equipment cleanout and are often described as washwater solids. Washwater solids usually are similar to, and managed along with, fly ash captured in the air pollution control system.

- **Bottom ash.** The heavier fraction of the waste stream that collects in the bottom of the boiler and is removed either manually or by gravity. Bottom ash includes a small amount of boiler slag that adheres to the boiler surfaces. The slag fraction must be removed by chiseling, jackhammering, sootblowing, or sandblasting.

In addition to the large-volume combustion wastes, oil combustors generate certain low-volume wastes similar to those generated by coal combustors. These low-volume wastes are the result of supporting processes (see Section 6.1.4) that are ancillary to, but a necessary part of, the combustion and power generation processes. These wastes may include the following:

- **Boiler blowdown.** Waste that is continuously or intermittently removed from boilers that recirculate water.

These facilities burn less fuel because of their capacity and are less likely to operate air pollution control devices.

- **Cooling tower blowdown and sludge.** Wastes removed periodically from closed-loop cooling systems.

- **Water treatment sludge.** Wastes resulting from treatment of makeup water for the steam cycle or for noncontact cooling.

- **Regeneration waste streams.** Wastes resulting from periodic cleaning of ion exchange beds used to remove mineral salts from boiler makeup water.

- **Air heater and precipitator washwater.** Wastes resulting from the periodic cleaning of the outside (fireside) of heat exchanging surfaces.

- **Boiler chemical cleaning waste.** Wastes resulting from the periodic cleaning of the inside (waterside) of boiler tubes with chemical solutions.

- **Floor and yard drains and sumps.** Wastewaters collected by drains and sumps and include miscellaneous drainage from the plant site, including precipitation runoff, piping and equipment leakage, and washwater.

- **Laboratory wastes.** Wastes generated in small quantities during routine analysis of fuel, intake water, wastes, and other samples at a plant site.

Finally, at most oil-fired utilities, fly ash (and sometimes bottom ash) is transported wet to solids settling basins (SSBs) (see Section 6.3), often using equipment washwater. Often, low-volume wastes also are managed in these basins. The periodic dredging of solids from these basins results in the generation of a waste stream known as SSB solids. SSB solids are composed of fly ash and solids settled from washwater and other low-volume wastes.

Comprehensive industry-wide data on the generation of OCWs are not available. Estimates by EPRI are available for the utility sector. Extrapolation has been made based on these estimates and relative fuel usage in order to also characterize waste generation in the non-utility sector.

For the utility sector, EPRI has estimated that between 15,000 and 90,000 tons of oil ash are “generated” annually. As discussed in Section 6.1.2, only a portion of the fly ash generated is collected. An estimated total of 23,000 tons of OCW were collected by utility oil combustors in 1995 (EPRI, 1998a).[2] This quantitative estimate is less than one one-thousandth of the quantity of large-volume utility coal combustion wastes generated in 1997 (105-million tons).

For oil-fired non-utilities, less total ash is expected to be generated because of air pollution control technologies and fuel characteristics (see Sections 6.1.2 and 6.1.3). EPA estimates that 5,500 tons of ash should be generated annually by non-utility oil combustion operations. While non-utilities and utilities burn comparable amounts of residual oil, the limited application of air pollution control devices at non-utilities results in significantly lower aggregate ash generation. Using EPA’s estimate in the 1990 U.S. EPA National Interim Emission Inventory (EPA, 1990) (5,245 oil-fired boiler units in the non-utility sector), the average non-utility OCW generation rate would be just over 1 ton per unit per year.

[2] According to EPRI, a conservative “high” estimate would be about 70,000 tons, assuming most waste is handled wet and then dewatered to 60 percent water content.

The portion of OCW generated that represents bottom ash versus fly ash varies greatly depending on fuel type and combustion technology. In some cases, the quantity of bottom ash generated is so low that it is collected infrequently. EPRI, in a study of 17 utility oil combustors, found the amount of bottom ash collected to be between 6 percent and 25 percent of the amount of fly ash (EPRI, 1998a). A general rule of thumb in the industry is that 70 percent of the ash generated (emitted and collected) should be fly ash versus 30 percent bottom ash (Stultz and Kitto, 1992).

Little information is available on the rates at which low-volume wastes are generated at oil-fired utilities; however, EPRI reports that oil-fired units typically generate boiler fireside washwater at a rate of 7 gallons per day per MW. EPRI estimates air preheater washwater generation to be at a rate of 17.6 gallons per day per MW, or 2.5-million gallons per year for a 400-MW baseload unit (EPRI, 1998a).

6.1.1 Combustion Technology

Two technologies are currently used for oil combustion: steam electric boilers and combustion turbines (CT). Combustion turbine operations use exhaust from oil combustion directly to drive turbines that produce electricity. Because the exhaust must be free of particulates (e.g., ash) that would damage the turbine, natural gas or high-grade fuel oil (i.e., distillate oil) is typically burned. Thus, ash generation from this technology is reportedly low. For example, one CT facility discussed in the EPRI 1998 Oil Combustion By-Products Report generated about one-half ton of bottom ash per year (EPRI, 1998a). Because CTs produce little ash, the focus of this discussion will be on steam electric boilers.[3]

Oil-fired steam electric units are conceptually similar to coal combustion units: they combust oil in a boiler to produce steam, which is in turn used to provide heat or steam or drive turbines that generate electricity. Box 6-1 provides a general overview of this technology. Oil-fired steam electric boilers, especially in the utility sector, burn a relatively low grade and, therefore, less expensive oil (i.e., residual oil, typically Number 6 fuel oil). As discussed in Section 6.1.3, the combustion of this type of fuel results in the generation of significant amounts of OCW.

Box 6-1. Oil-Fired Steam Electric Boiler Technology

In steam electric generation, atomized oil and preheated air are combined in a boiler and combusted. Oil for combustion is atomized to very small droplets, producing high surface to volume ratios. Atomization may be accomplished mechanically, with the pressure of the fuel itself providing the energy for atomization, or with the assistance of pressurized steam or compressed air. The residual oils typically used for steam generation require heating to reduce their viscosity prior to atomization. The atomized fuel is injected into the furnace in a fine mist through specially designed burners.

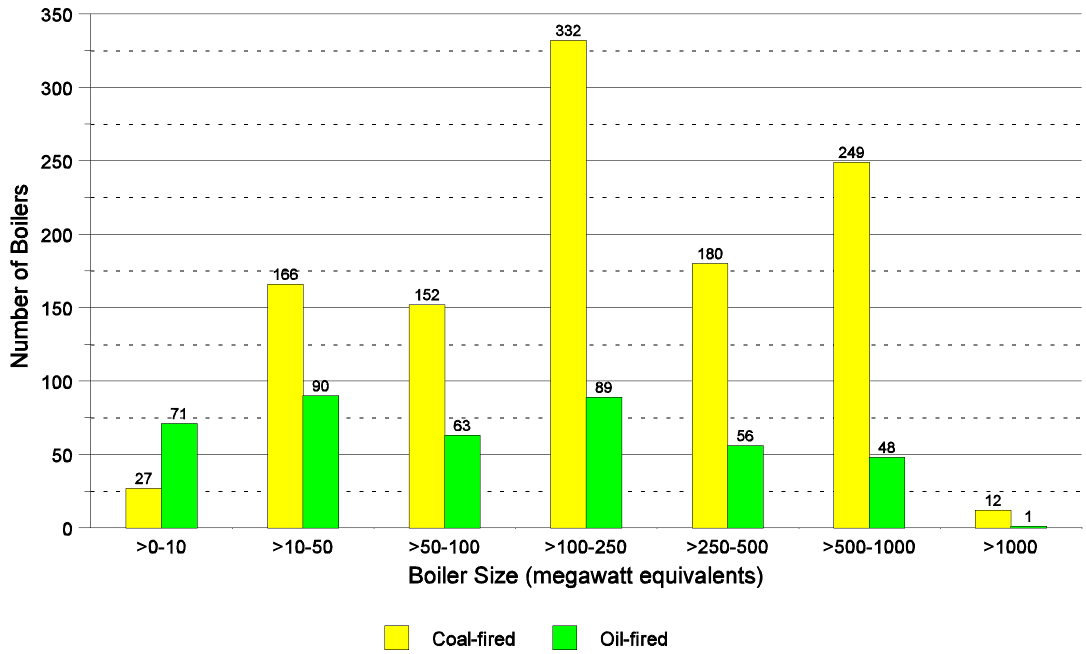
The burners disperse the fuel stream into a stream of preheated combustion air. In a typical oil combustion unit, air entering the boiler is preheated in a heat exchange unit (i.e., an air preheater). These are typically rotating, basket-shaped devices that pass alternately through the flue gas (i.e., hot gas leaving the boiler) and combustion air streams (i.e., unheated air entering the boiler). Heat recovered from the flue gas is transferred to the incoming air to increase boiler efficiency. Air preheaters collect ash from the flue gas and must periodically be cleaned to maintain maximum efficiency.

Sources: Stultz and Kitto, 1992; EPRI, 1998a

[3]Oil-fired CT ash, however, is covered by this study.

Oil-fired utility boilers are smaller on average than coal-fired boilers. This is because the oil-fired utility population contains a higher proportion of small units, as shown in Figure 6-2. Nearly all of the small units shown in Figure 6-2, however, are peaking, cycling, or standby units. Baseload oil-fired boilers (average 269 MW) are similar in size to coal-fired utility boilers (average 256 MW). Based on the average size reported in the 1990 U.S. EPA National Interim Emissions Inventory (just over 10 MW equivalent), oil-fired non-utility boilers are much smaller than utility boilers. Because of their smaller size, oil-fired non-utility boilers generate less ash on a per-boiler basis and likely are subject to less frequent cleanout.

Figure 6-2. Capacity of Utility Oil-Fired and Coal-Fired Boilers



Source: EEI, 1994

6.1.2 Air Pollution Control Technologies

Because of the low sulfur content of the fuel, oil combustion units typically do not require flue gas desulfurization (FGD) technology; therefore, oil combustion does not generate FGD waste.

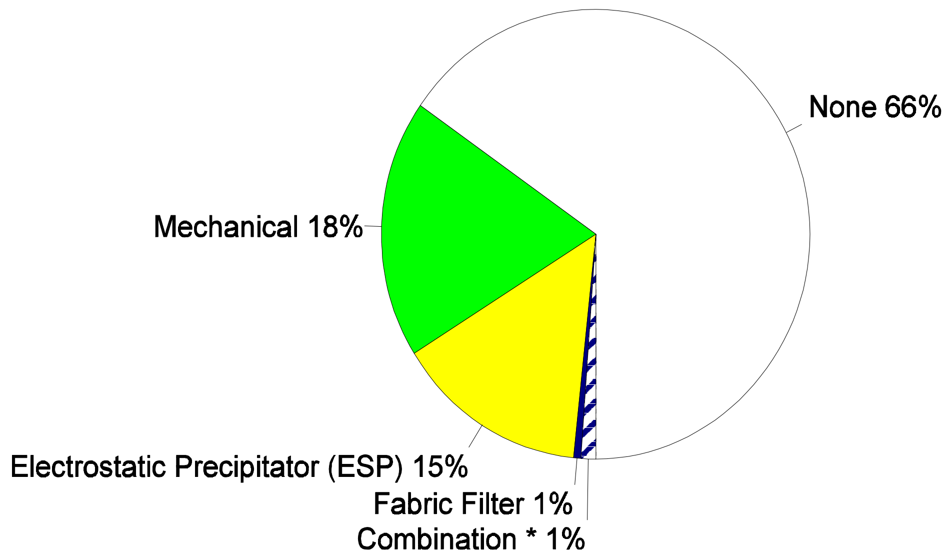
Although oil-fired utilities are subject to particulate matter restrictions similar to those for coal-fired utilities, particulate controls are utilized much less frequently at oil-fired facilities than at coal-fired plants. As shown in Figure 6-3, the majority (nearly two-thirds) of utility generating units that combust oil either as primary or as alternate fuel do not utilize particulate control equipment. This is due to three factors:

1. Because of the relatively low ash content of the fuel (see Section 6.1.3), the rate of emission may be low enough to not require control.

2. The physical size of a large fraction of oil fly ash (see Section 6.2) is below that currently regulated under the Clean Air Act (CAA).

3. The size (i.e., MW capacity) of many of the facilities (see Section 6.1.1) is such that they fall below thresholds for regulation under the CAA (see Section 6.5).

Figure 6-3. Particulate Control Technologies at Oil-Fired Utilities



*Mechanical collector followed by ESP.
Note: Percentages shown are of 354 units identified that burned oil in 1994. Total may not sum to 100 due to rounding.
Source: EEI, 1994

While particulate control use for oil-fired units overall is low, the larger utility oil combustion facilities are more likely to incorporate controls (see Table 6-2). As size decreases, oil-fired utilities are less likely to apply controls. Because of their smaller size distribution, oil-fired non-utilities are expected to be even less likely than utilities to apply controls. This, in turn, would mean less fly ash is collected for management in the non-utility sector.

Table 6-2. Particulate Control by Size of Utility Oil Combustion Unit

Utility Units* with Capacity	Percent of Total Units within Size Category	Percent of Total in Size Category with Particulate Control
Over 500 MW	14%	39%
Between 101 and 500 MW	42%	39%
Under 100 MW	44%	29%

* 354 units at 177 facilities burned oil in whole or in part in 1994
Source: EEI, 1994

The same technologies are used to control particulates at oil-fired utilities as at coal-fired utilities. Chapter 3 provides general descriptions of these technologies. When applied at oil-fired units, the collection efficiencies of these technologies varies due to fly ash characteristics and combustion conditions, as shown in Table 6-3. Even at its most effective, oil ash capture is less efficient than coal ash capture. The lower collection efficiency means less fly ash to be managed by oil combustors.

6.1.3 Fuel Usage

Like ash from coal combustion, oil ash results from uncombusted materials in the fuel; therefore, OCW generation is affected by the ash content of the fuel. The ash content of fuel oils varies depending

Table 6-3. Relative Removal Efficiencies of Particulate Control Technologies

Fuel	Control	Conditions	Removal Efficiencies	Comments
Oil	Mechanical	Normal operations	30%	Due to the small particle size of oil fired systems; particularly in units with reburn systems
		Unusual operating conditions (upsets, dirty oil, cleanouts)	up to 85%	Capturing larger particles associated with unusual conditions
	Electrostatic Precipitators (ESP)	Older combustion units	40–60%	Less efficient; carbon factor*
		Newer combustion units	70–90%	Smaller particle size and higher carbon content* than coal ash
Coal	Mechanical	Normal operations	up to 90%	Most efficient for largest particles
	Electrostatic Precipitators	Normal operations	99%	Large particles, lower carbon content

*A higher carbon content results in a lower resistivity of fly ash and, therefore, less effective collection by the electric field in an ESP.
Sources: EPRI, 1998a; Stultz and Kitto, 1992; EPA, 1998c; Elliott, 1989; DOE, 1993

on type. Fuel oils are classified according to the point of production in the distillation process, which separates crude oil into various oil fractions according to vapor pressure. For purposes of this discussion, the significant fractions resulting from distillation are distillate oils (including No. 1, No. 2, and No. 4 fuel oils) and residual oils (including No. 5 and No. 6 fuel oil and Bunker C oil). Because oil-fired boilers provide a wide range of fuel flexibility, the same burner technology can be used to combust a variety of fuel oil grades.

As shown in Table 6-4, all types of fuel oil have a much lower ash content than coal. This is a significant factor contributing to the much lower generation of waste by oil combustors. Furthermore, of the types of fuel oil, only residual oil has a significant ash content. Distillate oil generates little or no ash.

Table 6-4. Relative Ash Content by Weight

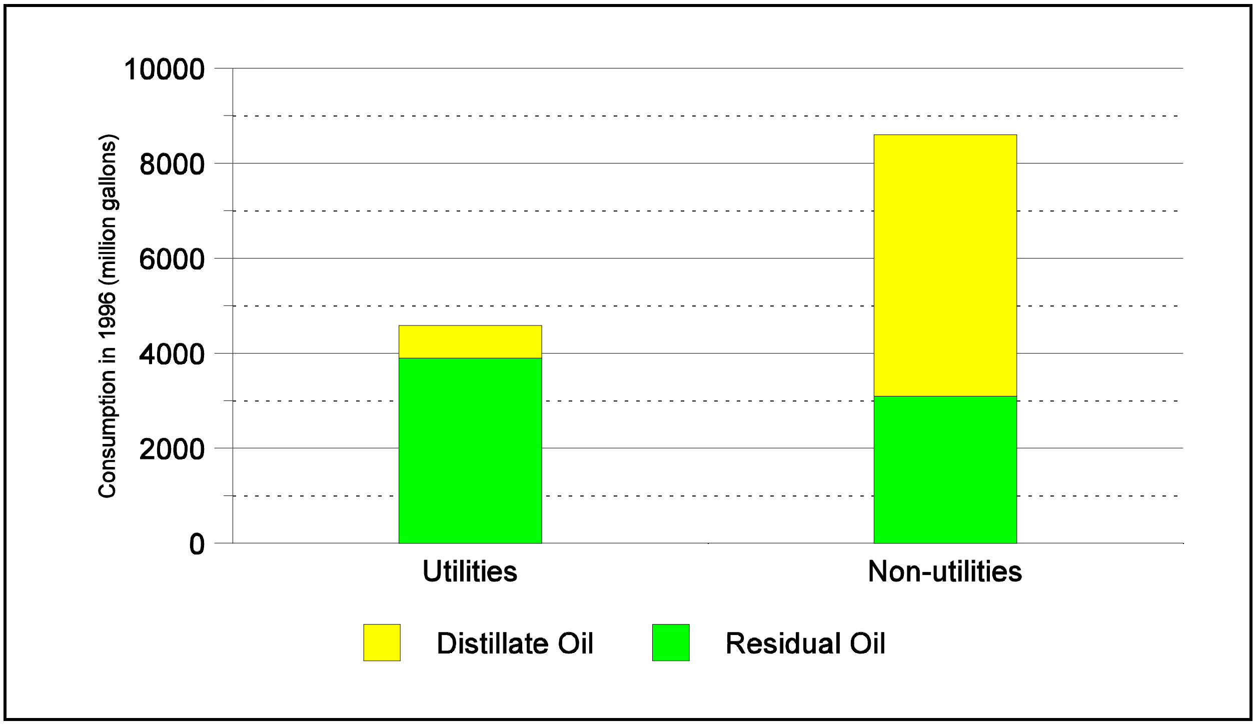
Type of Fossil Fuel			Percent of Ash by Weight
Coal:	Anthracite and Lignite		4 to 19%
	Bituminous		3 to 32%
	Average:	1975	13.5%
		1996	9.22%
Oil:	Residual Oil (No. 6 fuel oil)		less than 1% (0.009 to 0.16)
	Distillate Oil (No. 2 fuel oil)		negligible

Sources: CIBO, 1997c; DOE, 1993; EIA, 1996f; EPRI, 1998a

As presented in Figure 6-4, most of the oil burned by electric utilities is residual fuel oil. At utilities, distillate oil, which is more costly than residual oil, is used mainly for boiler startup prior to combusting residual oil and coal.[4] The less expensive residual oils, particularly No. 6, are the primary

[4] EPA's 1993 Regulatory Determination covered coal combustion wastes where oil is used as a start-up fuel and for flame conditioning.

Figure 6-4. Oil Consumption by Utilities and Non-Utilities



Source: EIA, 1997f

fuels for oil-fired utilities (EPRI, 1998a). Non-utility fuel usage, in contrast, favors the distillate oils. As a result, despite the greater total oil-fired capacity of non-utilities, utilities burn more *residual* oil and, thus, generate more waste. The total annual amount of residual oil used by utilities is about 800-million gallons more (about 26 percent) than that used by non-utilities.

Fuel characteristics affect waste generation in other, less direct ways as well. For example, corresponding to its low ash content, fuel oil contains a large carbon content. Because of this, significant amounts of carbon may remain unburned, contributing to the waste volume. Certain plants reinject fly ash back into the boiler to increase the burn efficiency, lower the waste carbon, and reduce the net quantity of waste generated.

In addition to the inherent amount of non-carbon material in the original fuel, additives to the fuel account for some of the waste residual. EPRI reports that fuel additives are assumed to add a factor of two to the inorganic ash fraction. The most common additives are magnesium-based compounds added to control slagging and corrosion caused primarily by vanadium in the oil; the amount added typically varies in proportion to the amount of vanadium present.

In addition to residual and distillate fuel oils, some oil-fired utilities in the United States have considered burning a new type of fuel, called Orimulsion. Orimulsion is the trademark name of a fuel produced in Venezuela that is a mixture of water (30 percent) and bitumen (70 percent), a heavy hydrocarbon. Orimulsion performs similarly to No. 6 fuel oil and can be burned using existing oil-fired boilers. Worldwide, only a few facilities, primarily in Japan and Canada, have begun firing Orimulsion on a commercial basis. No facilities in the United States currently burn Orimulsion. Therefore, this chapter focuses on wastes from standard fuel oils.

6.1.4 Supporting Processes

The generation of low-volume combustion wastes is associated primarily with processes that support the combustion process or make use of the products of combustion. Some of the same supporting and enabling processes can accompany combustion at oil-fired facilities as at coal-fired facilities, with the obvious exceptions of coal storage and coal processing. Little if any fuel oil processing occurs at oil combustion sites. Thus, the types of supporting processes at oil combustors include the following:

- Steam generation
- Cooling
- Water treatment
- Cleaning and maintenance.

Chapter 3 describes these processes in detail. The discussion below describes some aspects of these processes that are relevant to waste generation at oil combustors; however, quantitative information on the amounts of low-volume combustion wastes generated at oil combustors is scarce.

The supporting process of primary concern at oil-fired utilities is equipment cleaning operations. Boiler chemical cleaning wastes and equipment washwater frequently are comanaged with OCWs in the settling basins that generate SSB solids (see Section 6.3). At oil-fired utilities, cleanout operations addressing fireside equipment (boilers, flues, hoppers, and stacks) are performed periodically (e.g., yearly or less frequently) while units are not operating. Deposits in fireside equipment are typically removed using high pressure water, although alkaline (caustic) or acidic solutions may be used. Heat exchange units such as the air preheaters and economizers are typically cleaned more often (e.g., quarterly, monthly) to maintain boiler efficiency. Slag on the walls of boilers may in some circumstances require physical cleaning (i.e., jackhammering or chiseling); in other cases compressed air (i.e., sootblowing) may be used (EPRI, 1998a).

6.2 WASTE CHARACTERISTICS

The available data to characterize OCWs are from utilities. The Agency believes that OCWs at non-utilities have the same characteristics as those at utilities due to the use of the same fuel types and combustion technologies.

6.2.1 Physical Characteristics

Oil fly ash is a solid composed of fine particles. The particles are characterized by a smaller size distribution than coal fly ash. The typical median diameter is a few microns compared to median diameter of 10 to 20 microns for bituminous coal ash. Eighty percent of oil fly ash particles are smaller than 15 microns in diameter (EPRI, 1998a).

Oil bottom ash also is a solid, but is made up of heavier particles that are not entrained in flue gas. Some bottom ash may form a fused solid in the boiler that must be broken up to be removed.

OCWs (particularly fly ash and sometimes bottom ash) often are sluiced to SSBs, where they are managed along with equipment washwaters and other plant wastewaters. Solids settled from these basins are known as SSB solids and are composed primarily of fly ash captured either in particulate control units or in operational equipment (economizers, air preheaters) (EPRI, 1998a). Because they result from wet management, SSB solids have a much higher moisture content than other OCWs.

6.2.2 Chemical Characteristics

Major constituents of oil fly ash include silicon, iron, sulfur, magnesium, vanadium, aluminum, sodium, calcium, nickel, and potassium. These constituents are present primarily in the form of oxides. In most cases, their presence can be traced to the inorganics contained in fuel oil. Magnesium content may be high when it is used as a fuel additive to control slagging. Most of the unburned carbon from oil combustion is partitioned into the fly ash stream; oil fly ash may contain 30 to 80 percent unburned carbon. For the calculation of ash generation discussed in Section 6.1, EPRI used the value of 67 percent unburned carbon.

Bottom ash, in contrast, contains little unburned carbon. It is generally higher in silicon than fly ash, with other major constituents present in similar concentrations to fly ash. Because they are composed primarily of fly ash from the particulate control operations and the air preheater and economizers, SSB solids are chemically similar to fly ash in their major constituents. A notable difference is in the iron content in the SSB solids, presumably resulting from precipitation during treatment (EPRI, 1998a).

Based on available data on organics (see Section 6.2.3), dioxins, and nonmetallic inorganics, EPA believes metals are the class of constituents of concern in OCW. Oil ash can contain high levels of vanadium and nickel, and varying levels of other trace elements. Table 6-5 presents observed concentrations for these constituents.

6.2.3 Leaching and Hazardous Waste Characteristics

Using data available on the composition of OCWs, EPA evaluated whether the waste exhibited any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and toxicity. Based on available information and professional judgment, EPA believes that OCWs are not reactive or ignitable. Fly ash and bottom ash cannot be considered corrosive under EPA's definitions because the characteristic does not apply to solid materials. Furthermore, pH data are available for 29 samples of OCW from six sites (presumably from ash sluice water or liquids entrained in SSB solids). None of these samples exceeded the limits for corrosivity (pH less than or equal to 2 or greater than or equal to 12.5). The range of pH exhibited by these samples was 2.97 to 10.8.

EPA evaluates the characteristic of toxicity using Toxicity Characteristic Leaching Procedure (TCLP) results. Table 6-6 presents observed TCLP results for OCWs for a number of constituents. These include the eight metals regulated under the Resource Conservation and Recovery Act (RCRA) and several other metal constituents. Data also are available from Extraction Procedure (EP) tests (a test previously used by EPA to evaluate toxicity) for most of these same constituents (plus several others). The EP results are generally similar to or lower than the TCLP results shown in Table 6-6, with the exception of arsenic in bottom ash and arsenic and mercury in SSB solids, which appear in EP results at somewhat higher levels. The discussion below addresses the leachate data first for RCRA-regulated constituents, then for non-RCRA-regulated constituents.

Based on the TCLP and EP data for the eight RCRA metals, OCWs exhibit the RCRA characteristic of toxicity only infrequently. Table 6-7 summarizes data on the frequency of exceedences of the toxicity characteristic. Out of 176 samples analyzed by TCLP or EP, only 11 (6 percent) exceeded the regulatory threshold for one or more of the characteristic metals; however, these exceedences were spread across a relatively large number of sites. Seven sites out of the 40 for which data are available (18 percent) had at least one sample that exceeded a regulatory threshold. Details of these exceedences are as follows:

- Chromium was the metal with the most exceedences (five); most of these were in samples of solids from equipment washwater. Chromium exceeded the threshold in four samples of wash solids collected at three sites and in one of three samples of bottom ash at a fourth site.

- The site that had an exceedence for chromium in bottom ash also exceeded the threshold for lead in two of three bottom ash samples.

- Arsenic exceeded the threshold in one of two samples of bottom ash at one site and one of four samples of composite ash at another site.

- The site that had an exceedence for arsenic in composite ash also exceeded the threshold for cadmium in two of four samples of composite ash (one of these samples was the same one displaying the characteristic for arsenic).

- One of nine samples of fly ash from one site exceeded the threshold for selenium. The eight other samples of fly ash from the same site did not exceed the threshold; seven of these were below detection limits.

Table 6-5. Facility Average Concentration of Selected Constituents in OCWs (parts per million)

	Fly Ash		Bottom Ash		SSB Solids	
Constituent	Mean	Range	Mean	Range	Mean	Range
Arsenic	82.0	34.0–198	23.5	3.6–52	210	6.28–1,650
Barium	907	330–2,500	594	248–820	317	7.18–980
Boron	35.9	21.3–50.4	33.5	12–55	160	160–160
Cadmium	6.98	2.92–9.93	3.12	0.50–4.77	5.5	0.2–21.7
Chromium	1,016	138–4,000	205	33–675	456	13–1,250
Cobalt	233	233–233	n/a	n/a	51	51–51
Copper	587	270–920	789	154–2,860	2,250	69–16,460
Lead	515	288–1,334	108	57–176	622	46–1,773
Manganese	331	120–698	327	200–520	868	72–2,600
Mercury	5.96	0.06–23.5	0.993	0.081–2.80	0.22	0.108–0.38
Nickel	9,997	4,300–24,562	13,654	1,950–44,136	9,410	2,410–32,350
Selenium	11.1	0.4–17.7	6.07	2.16–10	13.4	0.79–35.0
Silver	3.16	1.06–5.98	n/a	n/a	3.9	0.05–9.7
Vanadium	48,816	22,528–110,647	55,541	8,749–200,000	31,580	880–69,670
Zinc	1,735	880–2,009	458	183–744	830	74–4,010

Note: All measurements identified as below detection limit were assigned a value equal to one-half the detection limit for use in the calculations. All concentrations are facility-averaged; i.e., multiple measurements from a single site are averaged, and the resulting population of facility averages used to generate the statistics in this table. Statistics presented here are based on a varying number of samples, depending on the constituent. For details, refer to the *Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Waste Characterization*.
n/a = data not available
Source: EPRI, 1997a

Table 6-6. Facility Average TCLP Results for OCWs (mg/l)

Analyte	RCRA Standard	Fly Ash		Bottom Ash		SSB Solids	
		Mean	Range	Mean	Range	Mean	Range
RCRA Toxicity Constituents							
Arsenic	5.0	0.319	0.01–1.5	0.391	0.025–3	0.0666	0.0015–0.321
Barium	100.0	0.370	0.105–1	1.88	0.025–12.9	0.647	0.09–1.7
Cadmium	1.0	0.160	0.005–0.520	0.130	0.00075–0.62	0.0187	0.005–0.04
Chromium	5.0	0.447	0.005–1.17	0.387	0.02–3.44	0.0621	0.005–0.279
Lead	5.0	0.164	0.03–0.325	1.23	0.012–13.4	0.0824	0.01–0.0625
Mercury	0.2	0.00108	0.0001–0.0025	0.00133	0.0001–0.00563	0.00269	0.0001–0.0005
Selenium	1.0	0.0622	0.0025–0.183	0.0887	0.0025–0.250	0.0605	0.0025–0.302
Silver	5.0	0.0248	0.00052–0.05	0.0542	0.0002–0.175	0.0353	0.005–0.145
Non-RCRA-Regulated Constituents							
Cyanide	n/a	n/a	n/a	0.264	0.264–0.264	n/a	n/a
Nickel	n/a	n/a	n/a	30.7	3.3–58	28.8	13–44.5
Vanadium	n/a	397	36.4–882	211	33.2–513	114	0.01–448

Note: All measurements identified as below detection limit were assigned a value equal to one-half the detection limit for use in the calculations. All concentrations are facility-averaged; i.e., multiple measurements from a single site are averaged, and the resulting population of facility averages used to generate the statistics in this table. Statistics presented here are based on a varying number of samples, depending on the constituent. For details, refer to the *Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Waste Characterization*.
n/a = data not available
Source: EPRI, 1997a

Thus, while OCWs overall rarely display the toxicity characteristic, a fraction of sites have a single OCW stream that exceeds the threshold for one or more metals in a large percentage of samples.

TCLP and EP leachate data also are available from 25 sites for toxic organics in OCWs. Of 57 samples, only 6 resulted in analyses above detection limits for one or more organics (one sample for benzene, one for chloroform, one for methyl ethyl ketone, two for chloroform and methyl ethyl ketone, and one for chloroform and 1,2-dichloroethane). None exceeded the regulatory thresholds for toxicity. Because of the low frequency of detection and EPA's experience with these specific organics as often being the result of laboratory contamination at reported levels, the Agency concludes that organics are not of further concern for OCWs.

Table 6-6 also shows TCLP data for three non-RCRA-regulated constituents: cyanide, nickel, and vanadium. Nickel and vanadium show high leachate concentrations, consistent with their high total concentrations in OCWs. Both these metals are considered further in Section 6.4, along with the RCRA toxicity constituents, in terms of their risk to human health and the environment. Cyanide was detected in only one of three samples at one site—insufficient data with which to evaluate its risk to human health and the environment. In addition, EP data are available for a number of other non-RCRA constituents, including calcium, chloride, copper, fluoride, iron, magnesium, manganese, nitrate, nitrite, sodium, sulfate, and zinc. Of these, copper, manganese, and zinc are considered further in Section 6.4.

Table 6-7. Frequency of Toxicity Characteristic Exceedences for OCWs[a]

TC Metal	Total Numbers		Toxicity Characteristic Exceedences			
	Sites	Samples	Number of Samples	Percent of Samples	Number of Sites	Percent of Sites
Arsenic	40	169	2	1%	2	5%
Barium	40	169	0	0%	0	0%
Cadmium	40	168	2	1%	1	3%
Chromium	40	176	5	3%	4	10%
Lead	40	176	2	1%	1	3%
Mercury[b]	40	169	0	0%	0	0%
Selenium	40	175	1	1%	1	3%
Silver	40	168	0	0%	0	0%
All TC Metals	40	176	11	6%	7	18%

[a] Table compares individual sample concentration data for fly ash, bed ash, composite ash, SSB solids, wash solids, and “other as h” analyzed by TCLP or EP, to the RCRA regulatory levels.

[b] One sample for mercury was reported as a non-detect with a detection limit more than twice the regulatory level. If assigned a value of one-half the detection limit according to the standard approach used in this report, the sample would be counted as an exceedence. However, given that no other samples approached the regulatory threshold for mercury, this apparent exceedence was assumed to be an artifact of the high detection limit and not counted here.

Source: EPRI, 1997a

6.3 CURRENT MANAGEMENT PRACTICES

The primary source used to evaluate the current waste management practices for oil combustion wastes was a recent study by EPRI of oil combustion byproducts (EPRI, 1998a) that contains detailed summaries of waste management practices at 17 large utility facilities that operate oil-fired units. Combined, these facilities reportedly account for 32 percent of oil-fired utility generating capacity and 46 percent of utility No. 6 fuel oil consumption. Of the 17 facilities, EPA used 15 for its characterization of the current management of oil combustion waste. One facility was not included because it was a combustion turbine unit; the second facility was disregarded because, although an oil facility, it was in backup status and was reportedly seldom used. This facility, furthermore, had no particulate controls and did not wash equipment. It reportedly was used so infrequently that routine cleaning was not necessary.

The management of OCWs varies depending on the type of waste (bottom ash, fly ash, low-volume wastes) and the type of facility (oil-fired facilities versus plants with both coal-fired and oil-fired units); therefore, the 15 facilities studied were divided into two groups: those that generated both CCWs and OCWs onsite (2 facilities) and those that generated only OCWs (13 facilities). Of this later group, eight also burned gas, while the remaining five were strictly oil operations. The common management practices observed at oil-fired utilities include onsite settling basins and offsite landfills, with a few onsite landfills (monofills handling only OCWs) represented.

Information regarding presence or characterization of management units at non-utility facilities combusting oil is not available. As discussed in Section 6.1, volumes of OCW are expected to be significantly smaller at non-utilities. Accordingly, onsite management units dedicated solely to OCWs (as observed at oil-fired utilities) are unlikely except at the largest non-utilities. Those few non-utilities that generate significant amounts of OCW likely manage the waste similarly to utilities. The smaller non-utilities likely manage OCW dry in offsite units or onsite in combination with non-combustion waste.

6.3.1 Facilities Generating OCWs Only

Ash Management

At facilities that generate only oil combustion wastes, oil fly ash and bottom ash are typically managed separately (see Table 6-8). Most commonly, fly ash is sluiced wet to a settling basin after collection by particulate control technology. This occurred at 10 of the 12 facilities that captured fly ash.[5] The remaining two facilities operate oil-fired baseload generation units and manage their oil fly ash in the following ways. One of these two facilities chemically thickens the ash slurry (and, on an "as-needed" basis, solids dredged from an onsite surface impoundment). The thickened material is drum filtered to dewater the material to about 50 percent solids. The filter cake drops into a rolloff box for immediate transportation to an offsite destination (landfill or vanadium recovery depending on the market). The supernatant from the filter operation is managed in surface impoundments with washwaters. This facility also collects bottom ash dry for offsite transport. The second of these facilities pneumatically transports its fly ash directly to an unlined onsite ash basin (landfill) where it is disposed with bottom ash. The facility operates a separate surface impoundment for washwaters.

Table 6-8. Combinations of OCW Managed

Description of Management	Number of Sites	Percent
Bottom ash and fly ash managed separately	9	69%
Bottom ash mixed with dredged solids from fly ash impoundments	2	15%
Bottom ash and fly ash comanaged dry in onsite landfill (ash basin)	1	8%
No particulate controls to collect fly ash; bottom ash collected	1	8%
Total	**13**	**100%**
Source: EPRI, 1998a		

The most common practice for the oil bottom ash is to collect it dry and transport it to an offsite destination (11 of the 13 facilities). Reportedly, the offsite destination is usually a landfill, unless the market is favorable for utilizing vanadium content in the ash. The remaining two facilities manage their oil bottom ash as follows. One of these facilities sluices its oil bottom ash to a surface impoundment (this is the facility that collects and manages no oil fly ash). The second facility transports its oil bottom ash dry directly to an onsite ash basin (landfill), where it is disposed with oil fly ash.

Low-Volume Waste Management

The practice of comanaging low-volume wastes is as prevalent for OCWs as it is for CCWs. Table 6-9 shows the frequency of comanaging OCWs and low-volume wastes for the 13 facilities studied. Because these "low-volume" wastes are liquid, they are typically managed in large quantities. For a typical site, the EPRI oil combustion report estimates a volume of 2.1-million gallons per year of the low-volume wastes, compared with 5-million gallons per year of fly ash sluice water.

[5] One of the 13 facilities had no particulate controls and did not collect fly ash.

Table 6-9. Comanagement of OCWs and Low-Volume Wastes

Description of Management	Number of Facilities	Percent
Comanagement of OCW and Low-Volume Wastes	11	85%
Low-volume waste comanaged with fly ash	(10)	(77%)
Low-volume waste comanaged with bottom ash	(1)	(8%)
No Comanagement	2	15%
Total	**13**	**100%**
Source: EPRI, 1998a		

The most common practice (11 of the 13 facilities) is for low-volume wastes to be comanaged in the same impoundments with fly ash. The two remaining facilities include one that disposes all ash dry in a landfill and a second that sends all ash offsite; these two facilities both operate impoundments for low-volume waste management. The types of low-volume waste most commonly comanaged are fireside washwaters, boiler chemical cleaning wastes, and equipment washwater and floor drains.

Settling Basin Solids Management

Solids from the surface impoundments (commonly called SSB solids) typically are dredged on an "as-needed" basis. The solids may be composed of several materials. At three of the EPRI oil combustion report sites, wastewater in the fly ash impoundments is specifically noted as being treated with coagulants (ferrous chloride and/or polymers) to precipitate metals and promote settling. This practice effectively results in commingling of fly ash with wastewater treatment sludge; other facilities also are likely to be using some chemicals in treatment. Ten of the 13 facilities sluice fly ash to these settling basins and their solids, therefore, contain fly ash as well as any treatment sludges. At one facility the solids include all the bottom ash generated. Solids from all facilities will include fly ash components that were captured in fireside equipment (air preheaters, economizers, stacks, fireside boiler surfaces) and subsequently washed down. Facilities that commingle boiler chemical cleaning waste for treatment also will have solids precipitated from this waste stream.

The most common practice for the SSB solids is to dredge them, dewater them, and transport them to an offsite destination.[6] Reportedly, the typical destination is an offsite landfill, unless the market is favorable for either utilizing vanadium content in the solids or using the solids in concrete applications.

Management Unit Description – Surface Impoundments

The surface impoundments used to manage sluiced ash and comanaged low-volume wastes at the 13 facilities in the study ranged from a tenth of an acre to nearly 13 acres (see Table 6-10). OCW waste management unit sizes range from small deep sump-like basins (the smallest acreage SSB unit is also the relatively deepest unit) to very large, relatively shallow surface impoundments. The system with the smallest capacity (just under 3,000 cubic yards) is only a half acre in surface area and between 3- and

[6] Only one of the 13 facilities reported leaving the solids in its basin. No fly ash is collected at this facility, it operates no baseload units, and the two basins were designed for other purposes, are cement-lined, and have very large capacities.

Table 6-10. OCW Management Surface Impoundment System Sizes[a]

Size Description	Adjusted Average [b]	Range (min–max)
Area	1.0 acres	0.1–12.8 acres
Capacity	9,038 cubic yards	2,968–123,655 cubic yards
Relative Depth [c]	6.5 feet	1.8–21.5 feet

[a] Size data are for combined settling basin system; SSB systems range in number of actual units from 1 to 4 with 2 being the most common.
[b] Two facilities were removed from this average as the units were originally designed for other uses and the sizes were significantly disproportionate to amount of wastewater managed (if included area would be 2.8 acres and capacity 26671 yd^3).
[c] Calculated using capacity and surface area, does not account for side slopes configuration.
Note: Depth data are derived from the reported capacity and area for each site.
Source: EPRI, 1998a

4-feet deep. The adjusted average[7] size unit was a 1-acre system; the median after adjustment was 1.1 acres. The typical settling basin system has two ponds. Concrete sump-type basins tend to be smaller and deeper; ponds used for percolation/evaporation range larger but shallower (average depth for pond units was 4.4 feet).

Figure 6-3 describes the types of liners employed in the OCW surface impoundments for the 13 facilities studied. Based on EPRI data, about two-thirds of the OCW surface impoundments are lined. The unlined impoundments are all located in the southeast Atlantic or southeast Gulf coasts and are percolation basins designed to discharge to ground water. This practice of discharging to ground water is allowed under Florida's state wastewater permits. State ground-water standards are applied to these units outside a specified zone of discharge. According to the EPRI oil combustion report, two of these unlined percolation basins at one site were cleaned and rebuilt in 1995 to alleviate trace metal movement. The rebuilding included the addition of a sand filter layer to retain fine particles and a crushed limestone base. Two unlined percolation basins at another site also have crushed limestone bases. Although these designs do not prevent leachate as a liner would, they may serve as a form of environmental control because the limestone can provide pH control and the filter layer may slow the migration of certain other constituents in leachate. Ground-water monitoring is practiced at 50 percent or more of the onsite SSBs.

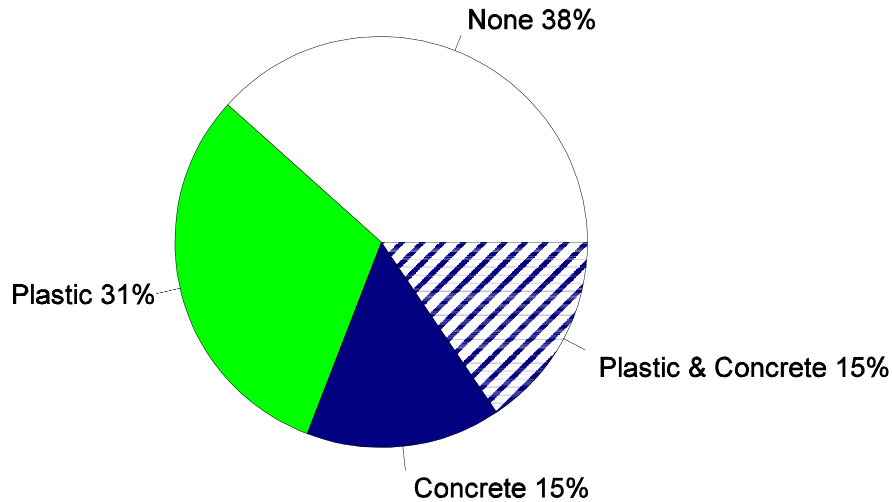
Limited data for these units suggest a trend toward the increasing use of liners. Three of the OCW surface impoundments were lined only recently—two in 1993 and one in 1996. In addition, one site that currently operates two lined impoundments historically used a single unlined basin. Furthermore, the major producer of power in Florida has verbally declared its intent to eventually line all units.

Management Unit Description – Landfills and Wastepiles

As noted above, the final disposition for most of the ash and SSB solids is in land-based disposal units, except when markets for vanadium recovery or other alternative use are favorable. With two exceptions, the waste is shipped offsite. No data are available on liners or other environmental controls employed at the offsite landfills.

[7] EPA calculated the adjusted average using 11 of the 13 facilities because two of the facilities operated units that were designed for other uses. The sizes of these units were significantly disproportionate to the amount of OCW wastewater managed.

Figure 6-3. Liners Used in OCW Surface Impoundments



Note: Percentages shown are of the 13 facilities studied.
Source: EPRI, 1998a

In the two instances of onsite management, some limited information was available in the EPRI report. Ground-water monitoring is performed at both sites. One facility utilizes an ash basin to which oil combustion fly ash and bottom ash are conveyed by dry collection and transport. Although it does not receive equipment washwaters or other plant wastewaters, the basin is described in the EPRI oil combustion report as part of a larger wastewater treatment complex, and appears from the accompanying map to be a cell built on the edge of a larger unit. It is unclear if standing water is maintained in the basin. The basin reportedly is unlined. The owners have indicated to EPRI that they intend to close the unit and ship ash offsite in the future. The second unit is described as a stabilized ash pad. The pad receives solids that are dredged from oil combustion fly ash surface impoundments and stabilized with a cement-based mixture. The pad has an asphalt cover and vegetated sides.

6.3.2 Facilities Generating Both OCWs and Coal Combustion Wastes

At facilities that generated both coal and oil combustion wastes, OCWs typically are comanaged with certain coal combustion wastes. Two facilities in the EPRI study were coal plants that each operated three coal-fired units along with a single oil-fired unit; these facilities are discussed below.

Ash Management

At both facilities, particulate controls in the form of electrostatic precipitators are used to capture oil fly ash. Neither facility reinjects oil fly ash into their oil units. One facility, however, does route about 70 percent of its oil fly ash to coal-fired units, where the high carbon content is reburned; any residue from this reburning is captured with the coal ash. The remaining oil fly ash at this facility, as well as all oil fly ash at the second facility, is sluiced to a surface impoundment system for treatment. The oil fly ash at both operations was at one point sent offsite for vanadium recovery. Both operations indicated that recent changes to low nitrogen oxide (NO_X) burners resulted in increased carbon content in the ash, making the relative proportion of the vanadium less and the recovery economics unfavorable.

Oil bottom ash from both operations is managed separate from oil fly ash; in one case it is comanaged with coal bottom ash. One facility collects it dry and trucks it to an offsite landfill. The second facility sluices the bottom ash to an impoundment that also manages bottom ash from the coal units. The combined coal and oil bottom ash is used for structural fill or construction applications; the majority of this waste would be expected to be coal ash.

Low-Volume Waste Management

All the low-volume wastes typical of oil-fired units are managed together with oil fly ash at these two facilities. These are routed at both facilities to pond-based wastewater treatment systems. All wastewaters at these two coal plants (e.g., bottom ash pondwater, coal pile runoff, floor drains) are routed to the same system; therefore, all oil fly ash and low-volume wastes from oil combustion are comanaged with low-volume wastes from the coal operations. Solids from these wastewater treatment impoundments are dredged at both facilities and sent to landfills, one onsite and the other offsite. Lime is added to both systems for pH control. Thus, wastewater treatment sludge is a component of the solids that settle from the wastewater.

Management Unit Description

The two facilities manage their OCWs in units similar to the SSBs used for oil-fired utilities. The facility that reburns most of its fly ash and ships its bottom ash to an offsite landfill (i.e., manages little ash in the SSB) uses a 1-acre SSB system. The three-basin system is unlined. Solids dredged from this basin are shipped offsite to a landfill; no data about this unit’s environmental controls are available. The facility that slurries all its fly ash, coal pile runoff, and bottom ash pond water operates a larger 2.8-acre SSB system. This two-basin system is high density polyethelene (HDPE)-lined. Dredged solids from this system are landfilled in a very large (i.e., over 60 acres as shown on map) landfill. The landfill, operated under a Massachusetts state permit, has 11 cells, 2 of which are currently active. The two active cells have double HDPE liners, leak detection, and leachate collection systems. At least 1 foot of standing water is maintained in the active cells to control fugitive dust. The nine inactive cells have single synthetic liners and are capped with a polyvinyl chloride cover, a drainage layer, and a soil top cover that has been seeded with grass.

6.3.3 Beneficial Uses

While comprehensive statistics do not exist on the quantities of OCW serving beneficial uses, there exist a few applications with the potential to serve as alternatives to traditional waste management for these wastes. In particular, the high metal content present in OCWs can make them a valuable resource for metals recovery. Vanadium, either in the form of oxides or carbides, may be recovered from oil fly ash and bottom ash through high-temperature or leaching processes. In turn, oil ash vanadium compounds are incorporated primarily as alloying agents or hardeners in steel manufacturing. While the vanadium in fly ash needs to be extracted prior to its addition into the smelting furnace, oil bottom ash can be added to the furnace directly due to its low carbon content. In addition to the steel industry, recovered vanadium compounds also serve as oxidation catalysts or as plasma-sprayed coatings in other industrial applications. The amounts of vanadium currently recovered from oil ash or utilized in any of the applications mentioned above are unknown. Reportedly, vanadium recovery from oil ash has been conducted, when economically viable, with OCW from 10 of the 17 oil-fired facilities studied by EPRI. Two of these facilities discontinued this practice in the early 1990s, following the installation of low nitrogen oxide (NO_X) burners, which increased the carbon content in the oil ash and affected the cost-effectiveness of the vanadium recovery process. One of the facilities reported sending all of its oil ash for vanadium recovery (EPRI, 1998a).

Some use of OCWs in construction applications also has been reported. Approximately half of the oil-fired facilities studied by EPRI reported sending some portion of their OCWs offsite for use in concrete products, as structural fills and roadbed fills, when the opportunity was available (EPRI, 1998a).

OCWs have not been used extensively for other beneficial use applications like those described in Chapters 3 and 5 for CCWs and FBC wastes. Since the quantities of OCW are much lower than those of CCWs and FBC wastes, the use of oil wastes may not be economically feasible in applications requiring large volumes of material. In addition, the high content of vanadium, nickel, aluminum, and molybdenum presents a barrier to OCW utilization, particularly as soil amendment.

6.4 POTENTIAL AND DOCUMENTED DANGERS TO HUMAN HEALTH AND THE ENVIRONMENT

Section 3.4 provides a discussion of the methodology employed by EPA in assessing risks from coal-fired utility comanaged wastes. EPA followed a similar approach for wastes from oil-fired boilers, with several important differences. First, as with FBC wastes, EPA received waste characterization data for sites representing roughly 30 percent of the generator population and an even greater percentage of wastes generated industry-wide. TCLP and EP Toxicity data were grouped to provide as large a sample population as possible. Second, EPA found that oil-fired utility waste generation and management practices differ significantly from those of their coal-fired counterparts (see Section 6.3). Oil-fired utilities commonly manage oil ash in very small onsite solids settling basins, from which ash is periodically removed for final disposal in an onsite or offsite landfill or for offsite processing for vanadium recovery. Offsite commercial landfills receiving oil ash typically are expected to be lined facilities (as discussed in Section 6.3 and 6.5). Accordingly, EPA developed scenarios for small unlined landfills and impoundments only. Finally, EPA found that oil-fired utilities reflect a geographic distribution distinct from coal-fired utilities, and so modified its modeling scenarios accordingly.

6.4.1 Potential Ground-Water Risks to Human Health

Table 6-11 summarizes selected results from the deterministic and probabilistic analyses of risk from OCWs for the adult receptor. EPA found that the risks associated with all modeled constituents of concern, except for arsenic, nickel, and vanadium, fell below a hazard quotient (HQ) of 1 or a lifetime cancer risk of 1×10^{-6}. Potential high-end risks associated with arsenic in the landfill and surface impoundment (solid settling basin) high-end deterministic scenarios exceeded 1×10^{-5}. Further, the predicted high-end HQs for nickel and vanadium exceeded 1 in both management unit scenarios; this was especially so for vanadium.

Comparison of the deterministic and Monte Carlo results reveals that the deterministic results generally exceeded the 95th percentile Monte Carlo results. For example, none of the 2,000 Monte Carlo simulation combinations of parameter values performed for nickel yielded a risk estimate as high as the corresponding high-end deterministic results. The deterministic result exceeded the 95th percentile Monte Carlo result for all constituents for the surface impoundment. This was not the case, however, for the landfill scenario. The 95th percentile Monte Carlo results for the landfill exceeded the deterministic results for arsenic and vanadium. These differences reflect the small number of data points in the sample population for several key variables, including waste concentration and management unit size, and are considered of little significance.

EPA also considered the time at which risks were predicted to result from the release of constituents of concern. As shown in Table 6-12, EPA found that the concentration of arsenic in ground water at the receptor well downgradient of the surface impoundment and the landfill would not reach the

Table 6-11. Comparison of Deterministic and Monte Carlo Risk Model Results for Oil Combustion Waste Ground-Water Pathway Scenarios

Scenario	Constituent[a]	Deterministic Risk, Central Tendency	Deterministic Risk, High-End	Corresponding Monte Carlo Percentile	Monte Carlo 95th Percentile
OS[b]	Arsenic	1×10^{-12}	7×10^{-5}	97.75	2.6×10^{-5}
	Nickel	HQ <1	HQ = 28	>100	HQ = 0.005
	Vanadium	HQ <1	HQ = 680	>99.9	150
OM[b]	Arsenic	1×10^{-15}	2×10^{-5}	93.45	3×10^{-5}
	Nickel	HQ <1	HQ = 1.8	>100	HQ = 0.05
	Vanadium	HQ <1	HQ = 6.7	85.9	HQ = 21

[a]All other metals modeled resulted in HQ <1
[b]OS = oil ash impoundment; OM = oil ash landfill
Note: Results shown are those from the October 10, 1998, Sensitivity Analysis.

Table 6-12. Predicted Time to Reach Risk for Oil Combustion Waste – Deterministic Scenarios

Scenario	Constituent[a]	Time to Risk (years)
OS[b]	Arsenic	400
	Nickel	50
	Vanadium	10
OM[b]	Arsenic	2,800
	Nickel	900
	Vanadium	80

[a]All other modeled metals yielded HQ <1
[b]OS = oil ash impoundment; OM = oil ash landfill
Note: Results are from the April 1998 Draft Final Report.

health-based level (HBL) for arsenic (i.e., achieve a risk level of 1×10^{-6}) for roughly 400 and 2,800 years, respectively. The times to reach the nickel and vanadium HBLs in ground water below the surface impoundment were considerably smaller at 50 and 10 years, respectively. The predicted near-term observations of nickel and vanadium in ground water also were corroborated by observations of these metals in ground water below actual waste management units (see Section 6.4.3).

Table 6-13 summarizes the estimated risks to adult and child receptors for the high-end deterministic scenario for OCWs. Overall, the results show that for non-carcinogens the risks for young children increased roughly twofold compared with the adult receptors. For arsenic, risks stayed at the 10^{-5} level for both adult and child.

Table 6-13. Comparison of Adult and Child Risk Model Results for Oil Combustion Waste – Ground-Water Pathway Scenarios

Scenario	Constituent[a]	High-End Deterministic Risk		
		Adult	Young Child	Child
OS[b]	Arsenic	7×10^{-5}	8.8×10^{-5}	6.2×10^{-5}
	Nickel	HQ = 28	HQ = 48.4	HQ = 31.4
	Vanadium	HQ = 680	HQ = 1,176.4	HQ = 761.6
OM[b]	Arsenic	2×10^{-5}	2.5×10^{-5}	1.8×10^{-5}
	Nickel	HQ = 1.8	HQ = 3.1	HQ = 2.0
	Vanadium	HQ = 6.7	HQ = 11.6	HQ = 7.5

[a]All other modeled metals yielded HQ<1
[b]OS = oil ash impoundment; OM = oil ash landfill
Note: Results shown are those from the October 10, 1998 Sensitivity Analysis.

6.4.2 Potential Above-Ground Multi-Pathway Risks to Human Health and the Environment

Human Health Risk Findings

No significant non-ground water human health risks were identified for landfill or impoundment scenarios.

Ecological Risk Findings

EPA found no significant ecological risks associated with releases from onsite landfills. EPA did not evaluate risks associated with standing waters in solids settling basins. However, because these basins are very small and because they are located within industrial facilities, the Agency believes that ecological impacts from direct exposure to these basin waters would be very small.

6.4.3 Documented Damages to Human Health and the Environment

EPA identified a total of nine sites managing oil combustion wastes that have ground-water contamination. Seven of the nine sites were documented in EPRI's oil combustion report (EPRI, 1998a). The two other sites were identified in supporting documentation for the 1993 Regulatory Determination and from RCRA Corrective Action records. EPA determined that ground water has been affected at all of these sites, though not always above maximum contaminant levels (MCLs) or other state standards. EPA, however, found that only one of these sites, the Possum Point, Virginia, facility previously described in the 1993 Supplemental Analysis and Section 3.4.3 of this Report, met the "test of proof" for a damage case.

Many of the sites evaluated are located next to the ocean or other large bodies of water where releases to ground water are discharged to surface water and no drinking water wells would be located between the management unit and the surface water. EPA did not find any cases of drinking water contamination or other environmental damages resulting from these releases. Additionally, most or all unlined units are operated under state permit allowing exceedences of ground-water standards close to the management unit but which must be met outside the zone of discharge. EPA found insufficient evidence of state action at these sites to meet the test of proof.

At two sites studied by EPA (Ft. Meyers, Florida; Possum Point, Virginia), the state required removal of oil ash waste from the management units. At the Possum Point facility, exceedences of constituents above primary MCLs were observed, while at the Fort Meyers facility no exceedences of MCLs were determined. Therefore, only the Possum Point facility (previously described in Section 3.4.3, damage cases related to comanaged coal combustion wastes) meets EPA's test of proof for identifying cases of damage.

Based on information available and consideration of EPA's "tests of proof," EPA identified the cases in Table 6-14 as potential damage cases.

Table 6-14. Potential Damage Cases

Damage Case	Wastes Present	Event	Test of Proof	Comment
Oil Combustion Wastes				
VEPCO – Possum Point (VA)	Coal ash, pyrites, oil ash, water treatment wastes, and boiler cleaning wastes	Ground water contaminated with Cd and Ni, attributed to pyrites and oil ash	Administrative	Response included sequestration of oil ash, pyrites, and metal cleaning wastes to separate lined units

6.5 EXISTING REGULATORY CONTROLS

EPA's objective in this analysis was to identify and evaluate the existing regulatory controls that pertain to the management of oil combustion wastes. The regulatory analysis is directed toward addressing the question of whether existing regulations are adequately protecting human health and the environment. The analysis also is helpful in understanding waste generation and current management practices.

The sections below discuss regulations addressing air pollution, water pollution, and solid and hazardous waste, respectively. Air regulations are relevant primarily because of their effect on waste generation. Water regulations have an influence both on waste generation and management and, in particular, address the impact of OCWs on surface waters. Solid and hazardous waste regulations are of the greatest interest because they directly govern waste management practices.

The sections below describe federal regulations in each of these areas. In many cases, the implementation of these federal programs is carried out by the states; therefore, where appropriate, aspects of state implementation also are discussed. Because the nuances of state implementation are of particular importance with respect to solid waste regulation, that section discusses state programs in detail.

6.5.1 Regulations Addressing Air Pollution

The CAA is intended to protect and enhance the quality of the nation's air resources. CAA requirements have been a significant factor affecting the generation and collection of certain OCWs (specifically, fly ash). The CAA requirements most relevant to OCWs include the following:

- National Ambient Air Quality Standards (NAAQS) for particulate matter (PM)
- NAAQS for sulfur dioxide
- NAAQS for ozone
- National Emissions Standards for Hazardous Air Pollutants (NESHAP).

Title IV acid rain provisions, the fifth set of requirements that affect fossil fuel combustors as a group, currently apply only to the largest coal-fired utility generating units and, therefore, are not relevant for oil-fired units. Historically, CAA requirements have been a significant factor affecting the generation and collection of certain OCWs. Recent and forthcoming changes in these requirements also may impact waste generation or characteristics, as discussed below.

NAAQS for Particulate Matter

The NAAQS for PM establish maximum concentrations of PM with diameter less than or equal to 10 micrometers (PM10) in the ambient air. These standards are among the factors motivating the use of particulate control technologies at FFC facilities. EPA recently proposed to lower the size criterion to 2.5 micrometers, which may affect the volume of fly ash collected and selection of control technology. Final standards, however, will not be issued for at least 5 years, so the impact of the new size criterion is difficult to predict at this time.

The NAAQS for PM are implemented through New Source Performance Standards and State Implementation Plans.

New Source Performance Standards (NSPS). The NSPS subjects newly constructed or, importantly in the case of oil-fired utilities, modified units to specific PM emissions limits. These limits may be met by changing fuel types, modifying combustion conditions, or installing control devices. The applicability of the NSPS and the specific limits imposed vary with the age and size of the combustion unit, with older and/or smaller units less likely to be subject to the NSPS. Specifically, the regulation of facilities can be considered in four categories.

- 40 CFR 60 Subpart D governs the standards of performance for new fossil fuel-fired steam generators that were constructed or underwent major modification after August 17, 1971. Subpart D affects only units that are capable of burning fossil fuels at greater than 73 megawatts (MW) of heat input rate.

- Subpart Da affects utility units with the capacity to fire fuel at greater than 73 MW heat input rate that commenced production or major modification after September 18, 1978.

- Subpart Db affects units with the capacity to fire fuel at greater than 29 MW of heat input rate that commenced construction or modification after June 19, 1984.

- Subpart Dc governs units constructed or modified after June 9, 1989, with capacity to fire fuel at less than 29 MW but greater than 8.7 MW of heat input rate.

With the exception of Subpart Da, which applies specifically to utilities, the NSPS requirements apply to all oil-fired steam generating units, utility or non-utility. Non-utilities, however, tend to have smaller capacities than utilities and, therefore, are more likely captured by those NSPS requirements that apply to smaller capacity units (i.e., Subparts Db and Dc). Note that under the NSPS regulations, facilities that were in operation before the dates stated in each of the four subparts are considered “grandfathered” and would not be subject to the new performance standards unless they underwent a major modification.

State Implementation Plans (SIPs). The performance standards above can be enforced by a federal, state, or local regulatory agency. There are additional CAA regulations that could require an oil-fired unit to install a particulate removal device notwithstanding the grandfather clause in Subparts D, Da, Db, and Dc. SIPs may impose, on a state-by-state basis, PM controls of varying stringency on specific sources or categories of sources, including oil combustion facilities. Such controls are required under Title I of the CAA if a particular area is in nonattainment for the NAAQS for a criteria pollutant such as PM. For this reason, SIP controls will generally be more stringent in such nonattainment areas. In attainment areas, the prevention of significant deterioration (PSD) program requires new sources to apply Best Available Control Technology (BACT), which must be at least as stringent as NSPS.

NAAQS for Sulfur Dioxide

Similar to the NAAQS for PM, the NAAQS for sulfur dioxide establish a maximum concentration of sulfur dioxide in the ambient air. The NAAQS for sulfur dioxide are implemented through NSPS and SIPs. The functioning and applicability of the sulfur dioxide NSPS requirements are similar to those for PM.

Each of the first three categories of oil-fired facilities regulated under Subparts D, Da, and Db is subject to the same requirement: sulfur dioxide emissions must be less than 340 nanograms per joule (ng/J) of heat input. Under Subpart Dc, facilities constructed or modified after June 9, 1989, with heat input capacity between 2.9 MW and 29 MW must limit emissions to less than 215 ng/J heat input. Facilities with greater than 22 MW heat input capacity generally also must achieve a 10-percent reduction in their sulfur dioxide emissions, based on the potential concentration in fuel. Facilities constructed or modified after June 9, 1989, and between 2.9 and 8.7 MW heat input capacity may meet the standard based on certification from the fuel supplier that the sulfur content of the fuel is low enough to meet the standard.

In addition to NSPS, states may impose controls through their SIPs to meet the sulfur dioxide NAAQS. These controls may vary in stringency depending on attainment status and may be placed on specific sources or categories of sources, including oil-fired units.

Because of the low sulfur content of fuel oil and the ability to switch fuel easily, the NAAQS for sulfur dioxide have not led to extensive use of FGD technology at oil-fired facilities.

NAAQS for Ozone

The NAAQS for ozone establish a maximum concentration of ozone in the ambient air. EPA recently lowered this concentration from 0.12 to 0.08 parts per million (ppm). The new standard allows four exceedences of the maximum in a region over a 3-year period. EPA expects states will meet the new standard by amending their SIPs to limit nitrogen oxide emissions at utilities. In proposing the new rule, EPA published a Regulatory Impact Analysis (RIA) forecasting changes in the operating practices of utilities that could result from these SIP modifications.[8] The RIA estimates that total utility capacity will increase by the year 2010. As a result of the new regulations, however, utilities are expected to invest in new combined cycle gas-fired units and oil- or gas-fired CTs to provide this new capacity. Oil-fired steam generating capacity is not expected to increase (EPA, 1997b; EIA, 1998a); therefore, utility generation of ash is not expected to increase dramatically, even with future expansion of the utility industry.

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[8] The RIA was based on a slightly more stringent ozone standard that allowed only three exceedences over a 3-year period and also incorporated the impacts of proposed changes to the PM standard that have not yet been finalized. Still, the general trends forecast by the RIA are expected to be valid for purposes of this analysis.

NESHAP

Under the NESHAP, EPA is required to establish technology-based standards for 189 hazardous air pollutants (HAPs). These standards are to be set on an industrial category basis and will apply to facilities that emit greater than 10 tons/year of any one HAP or greater than 25 tons/year of any combination of HAPs.

EPA has studied HAP emissions from utility oil-fired steam generating units and found that nickel from oil-fired utilities is a HAP of potential concern. EPA has deferred any determination as to whether regulations to control HAP emissions from utilities are appropriate and necessary (EPA, 1998c). If such regulations were promulgated, they could affect the characteristics or volumes of FFC solid wastes.

For non-utility oil combustors, EPA has not specifically studied HAP emissions. Because NESHAP will be set on an industrial category basis, when promulgated, the impact of these regulations on OCW generation and characteristics may vary depending on the industrial sector of the non-utility oil combustor.

6.5.2 Regulations Addressing Water Pollution

Under the federal Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) controls discharges to waters of the United States. As discussed below, the controls required under NPDES affect the collection and management of CCWs. In states authorized by EPA, these controls are implemented through state programs (often termed State Pollutant Discharge Elimination Systems, or SPDES). Because state programs must be at least as stringent as the federal program, the discussion here focuses on federal requirements as a lowest common denominator. NPDES requirements apply differently to two categories of discharges: process wastewaters and stormwater runoff. Neither the NPDES process wastewater or NPDES stormwater requirements make a distinction between oil-fired and coal-fired units. Distinctions may apply, however, between utilities and non-utilities.

NPDES Requirements for Process Wastewaters

The NPDES requirements that apply to process wastewaters from oil-fired utilities are those for the steam electric point source category under 40 CFR Part 423. These requirements apply to facilities "primarily engaged in the generation of electricity for distribution and sale" (i.e., utilities). Oil-fired non-utilities face NPDES requirements for process wastewaters that are specific to their industrial sector. In most cases, under these requirements each discharge requires an individual NPDES permit with numeric limitations based on Best Practicable Control Technology Currently Available (BPT), Best Available Technology Economically Achievable (BAT), or New Source Performance Standards (NSPS). Facilities that discharge to publicly owned treatment works (POTWs) rather than directly to surface waters face Pretreatment Standards for Existing Sources (PSES) similar to BAT, or Pretreatment Standards for New Sources (PSNS) similar to NSPS.

The majority of OCWs (and particularly fly ash) are managed wet. For these wastes, the most relevant requirements are total suspended solids (TSS) limits.

At non-utilities, the specific NPDES effluent standards applied depend on industrial category. Effluent standards expected to apply to large numbers of non-utility fossil fuel combustors include those for the following industry categories:

- Pulp, paper, and paperboard (40 CFR Part 430)
- Organic chemicals, plastics, and synthetic fibers (40 CFR Part 414)
- Inorganic chemicals manufacturing (40 CFR Part 415)
- Textile mills (40 CFR Part 410)
- Timber products processing (40 CFR Part 429)
- Iron and steel manufacturing (40 CFR Part 420)
- Sugar processing (40 CFR Part 409)
- Grain mills (40 CFR Part 406).

The standards for all of these categories include TSS limits, and these limits are applicable to nearly all of the industrial subcategories covered under each category. Some subcategories are subject to zero discharge requirements. Based on the Standard Industrial Classification (SIC) codes reported by non-utilities in the 1990 U.S. EPA National Interim Emissions Inventory (EPA, 1990) database, these industrial category requirements are expected to cover roughly 20 percent of non-utility fossil fuel combustors. A number of other facilities are scattered through other industrial categories, many of which are also subject to TSS limits. Some facilities (such as institutional fossil fuel combustors) may not be subject to the specific standards of any industrial category. In these cases, the specific effluent limitations would be determined on a case-by-case basis as part of the non-utility's individual NPDES permit.

At utilities, the steam electric category NPDES requirements place TSS limits directly on fly ash handling and bottom ash handling waters. In addition, the NSPS for the steam electric category include a zero discharge requirement for fly ash handling water. These steam electric requirements may also be incorporated in individual permits at non-utilities to supplement their industrial category requirements. Application of steam electric requirements to relevant waste streams at non-utility fossil fuel combustors is left to the best professional judgment of the individual permit writer (EPA, 1996).

Because of these requirements, when OCWs are managed in surface impoundments or settling basins, facilities may have to settle or otherwise remove a certain amount of waste solids from the handling water to meet the TSS limits prior to discharge. Zero discharge requirements effectively eliminate the release of waste solids to surface water. Thus, the requirements control the direct release of fly ash, bed ash, and any treatment solids to surface waters.

NPDES Requirements for Stormwater

NPDES stormwater requirements apply to stormwater runoff from FFC facilities, which may include runoff from operating areas, ash handling areas, and waste management units. Like the process wastewater requirements, stormwater requirements have been established on an industrial sector basis; therefore, the steam electric requirements apply to non-utilities just as they apply to utilities. A chemical manufacturer, for example, operating a fossil fuel-fired boiler must meet both chemical manufacturing and steam electric stormwater requirements.

Facilities can meet the stormwater requirements by including stormwater in their individual NPDES permit or seeking coverage under a general permit by submitting a Notice of Intent (NOI). Individual permit control and monitoring requirements will be facility-specific, subject to the judgment of the permit writer.

When covered by a general stormwater permit, requirements include implementation of a stormwater pollution prevention plan, "reasonable and appropriate" control measures, and 1 or 2 years of monitoring and reporting. No site visit by regulators is required under the general permit. Under the general permit approach, oil-fired facilities have a great deal of flexibility in selecting appropriate control measures for runoff that may have contacted OCWs. The general permit requirements include recommended best management practices for stormwater at steam electric facilities, landfills, treatment works, and construction areas greater than 5 acres. Because these requirements are additive across industrial sectors, an oil-fired utility with an onsite ash landfill, for example, must meet both steam electric and landfill requirements.

Because the stormwater program is relatively new and managed by authorized states, the number of facilities with general versus individual permits is not known. EPA handles NOIs for 10 nonauthorized states. In these states, 700 steam electric facilities (utility and non-utility) have filed for general permits.

6.5.3 Regulations Addressing Solid and Hazardous Waste

EPA regulates the management of solid and hazardous waste through Subtitles C and D of the RCRA. Subtitle C of the RCRA establishes a “cradle-to-grave” management system for wastes that are considered hazardous because they fail tests based on their physical and chemical characteristics (i.e., toxicity, corrosivity, ignitability, and reactivity) or because they are listed as hazardous by EPA. Federal regulations establish stringent environmental and administrative controls that must be applied to management of these wastes. OCWs, whether generated at a utility or non-utility, are currently exempt from federal regulation as hazardous waste under Subtitle C pending this Report to Congress and the subsequent regulatory determination. Therefore, these wastes are currently subject to the requirements of Subtitle D of the RCRA as nonhazardous solid waste.

Implementation of Subtitle D is the responsibility of individual states, but nothing prevents states from imposing more stringent requirements (including hazardous waste requirements) on FFC wastes. Although federal policy currently exempts OCW, like CCW, from Subtitle C regulation, state adoption of this exemption is not as extensive for OCW as for CCW. Only 26 states extend the federal exemption to OCW. These 26 states, however, represent more than 80 percent of oil-fired utility capacity. In the other states, any OCWs that fail the hazardous waste characteristic tests would be subject to state hazardous waste requirements and managed in units that meet permitting, design, operating, corrective action, and closure standards.

OCWs fail the hazardous waste characteristic tests only infrequently; therefore, the majority of OCWs that do not fail the hazardous waste characteristic tests and/or are generated in the states that duplicate the federal exemption generally would be subject to less stringent state requirements under Subtitle D. In the CIBO survey, 20 states (accounting for 60 percent of oil-fired utility capacity) indicated that their waste management requirements for oil combustion wastes differed from those for coal combustion wastes. To characterize these differing requirements, EPA examined solid waste regulations pertaining to OCWs in four states: Florida, New York, Massachusetts, and Pennsylvania. These states account for more than half of the oil-fired utility electric generating capacity. Table 6-15 summarizes the requirements in each of these five states.

Table 6-15. State Waste Management Requirements Applicable to OCWs in Selected States

Florida	
Landfill Requirements	Landfills must not cause ground water or surface water quality to exceed minimum standards outside a specified zone of discharge. Requirements include composite or double liners, leachate collection systems, run-on/runoff controls, ground-water monitoring, a cap including a geomembrane layer at closure, and revegetation at closure. State imposes a more stringent requirements as necessary due to site-specific conditions and types of waste disposed.
Impoundment Requirements	Regulations do not dictate any specific design requirements. Impoundments may be permitted to discharge to ground water as long as they do not cause ground-water quality to exceed minimum standards outside a specified zone of discharge.
Utility Siting Requirements	Utilities with generating capacity of 75 MW or greater must receive a certification to construct and operate under the Power Plant Siting Act. The certification process explicitly includes consideration of ash generation and the impacts of onsite solid waste management. This includes consideration of natural or manmade liners and leachate and runoff controls. The granting of certification can be subject to restrictions and requirements on any aspect of operation, including solid waste management.
Grandfather Clause	Landfills constructed before July 6, 1993, are exempt from the liner, leachate collection, and run-on/runoff control requirements.
New York	
Landfill Requirements	State has separate programs for landfills that accept mixed solid waste (including municipal solid waste landfills) and industrial or commercial waste monofills. Either may receive OCWs. Mixed solid waste landfill requirements include two composite liners, leachate collection systems, ground-water monitoring, daily cover requirements, cover at closure, and revegetation at closure. Industrial and commercial waste monofills are subject to similar requirements as those for mixed solid waste landfills; however, the state may impose additional or less stringent requirements based on the volume and characteristics of the waste. In practice, single composite liners typically have been required for these monofills.
Impoundment Requirements	Regulations do not impose any specific design requirements on surface impoundments managing OCW.
Grandfather Clause	Landfills permitted prior to October 9, 1993, are not required to retrofit liners or leachate collection systems, except for expansions of the facility.
Massachusetts	
Landfill Requirements	Specifically because of concerns about vanadium in oil ash, the state has developed an interim policy placing conditions on the disposal of OCWs from utilities. Coal and oil ash mixtures from utilities and OCWs from non-utilities are subject to the policy on a case-by-case basis. Under the interim policy, disposal of oil ash is subject to written approval. The waste may be disposed only at landfills with lined active disposal areas and leachate collection systems. It must be delivered damp to control fugitive dust and must be covered daily to prevent fugitive vanadium emissions. When landfilled according to the policy, OCWs may be handled similarly to residential refuse. They are not considered “special wastes,” which, under Massachusetts regulations, are nonhazardous wastes that require particular management controls to prevent adverse impact.
Impoundment Requirements	Regulations do not impose any specific design requirements on surface impoundments that manage OCWs. Units may be permitted to discharge to ground water.
Grandfather Clause	No specific grandfather clause; interim policy has been in place since 1983.

Pennsylvania	
Landfill Requirements	Landfills are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the landfill. Based on available characterization data, OCWs would sometimes require management in Class I or Class II units, with Class III management allowed for about 60 percent of waste. Liners are required for all classes, with liner type determined by class. Leachate collection and detection are required for Class I and II units. All classes are subject to the following: siting restrictions, fugitive dust control, daily cover, soil erosion control, ground-water monitoring, 2-foot clay cap at closure, and revegetation at closure.
Impoundment Requirements	Surface impoundments (including those that store waste for less than one year) are classified according to TCLP results for the wastes to be disposed. Specific design requirements depend on the class of the impoundment. Based on available characterization data, some OCWs would require management in Class I units, with Class II management allowed for about 80 percent of waste. Liners are required for all classes, with liner type determined by class. All classes also are subject to the following: siting restrictions, leachate detection system, leachate collection system, minimum freeboard requirements, structural integrity requirements, ground-water monitoring, 2-foot clay cap at closure, and revegetation at closure.
Grandfather Clause	Units permitted prior to July 4, 1992, were required to modify their operations to comply with the above requirements by July 4, 1997. Liner and leachate collection requirements may be modified if the operator could demonstrate that the unit had not caused unacceptable ground-water degradation.

Based on this detailed analysis, it appears states have varied in their application of solid waste management requirements to OCW landfills. For example, Pennsylvania's program imposes requirements tailored to the characteristics of the waste. Massachusetts' interim policy specifically addresses concerns over vanadium in OCWs. According to discussion with Florida waste management officials, the combination of solid waste and power plant siting regulations have not, in practice, resulted in any permit requirements specifically tailored to the onsite management of oil ash. Thus, Florida's and New York's programs apply generically to industrial wastes. In these states, OCWs may be disposed of in landfills that are "grandfathered" out of requirements imposing design requirements such as liners.

Regulations in three of the four states studied do not impose specific design requirements on surface impoundments that are commonly used to store OCWs. Two of these states permit discharges to ground water from these units.

6.6 WASTE MANAGEMENT ALTERNATIVES

The risk assessment identified potential ground-water pathway risks to human health from OCW in unlined landfills and impoundments. Mitigation of these potential risks might be accomplished through the use of technologies that prevent or contain and collect leachate from OCW landfills and surface impoundments. Specially, EPA identified the combination of technologies in Table 6-16 as an alternative that would be practical and effective to mitigate the potential ground-water risk. The technologies identified in the table are considered further in the cost and economic impact analysis. These technologies also are consistent with those required under Subtitle D of RCRA.

6.7 COMPLIANCE COSTS AND ECONOMIC IMPACTS

This section discusses the costs and economic impacts of risk mitigation alternatives for OCWs. Because of the quantity of waste generated and availability of data, the analysis focuses on wastes generated by oil-fired utilities only. Details of this analysis are documented as part of the EPA docket.

Table 6-16. Management Alternatives for OCW

Landfill	Impoundment
Design includes filter fabric, 1' sand layer, 2' clay liner, synthetic (HDPE) liner, leachate collection system, ground-water wells. Operation includes environmental monitoring and leachate collection and treatment. Closure requirements include 6" topsoil and vegetation, filter fabric, 1.5' sand layer, 2' clay layer, synthetic (HDPE) liner, cover drainage system. Post-closure includes environmental monitoring, landscape maintenance, slope maintenance, inspection, administration.	Design includes filter fabric, 1' sand layer, 2' clay liner, synthetic (HDPE) liner, leachate collection system, synthetic liner for sludge drying basin, ground-water wells. Operation includes environmental monitoring, leachate collection and treatment, solids settling and dewatering followed by disposal in landfill meeting standards at left. Closure requirements include final solids dredging and dewatering followed by disposal in landfill meeting standards at left, pressure washing sludge drying basin, 6" topsoil and vegetation, 1.5' soil layer, leachate sampling.

6.7.1 Overview and Methodology

In estimating costs and economic impacts for oil-fired utilities, EPA used a similar approach to that described in Section 3.7.1 for coal-fired utilities. Salient distinctions between the analysis in Section 3.7 and this analysis are reviewed below.

EPA's analysis began with the 89 oil-fired plants identified in the 1993 U.S. Department of Energy (DOE) Energy Information Administration (EIA) 767 database that have electrical generating capacities of at least 10 MW. EPA estimated the incremental compliance cost of the risk mitigation alternative described in Section 6.6. The cost estimate required oil-fired utilities to construct composite lined solids settling basins (SSBs). Because the few onsite landfills identified currently are lined and assuming that offsite landfills are compliant with Subtitle D, no incremental costs were estimated for OCW landfills.

The cost estimate summed costs in the following categories: initial capital costs, annual operating and maintenance costs, and closure costs. Recurring capital costs and post-closure costs were minimal for management units as small as the oil SSBs. Table 6-17 identifies the specific cost components included in each cost category for oil-fired utilities.

Similar to the analysis for coal-fired utilities, the cost estimate for OCWs employed three different SSB sizes. Table 6-18 identifies the design features for these basins. A single cost equation was developed, annualized costs were estimated as a function of facility-specific waste generation, and total industry costs were derived by summing the facility-specific estimates. Costs and economic impacts are set forth in the following three sections: incremental compliance cost, compliance cost impact on facilities as a function of size, and industry impact.

Incremental compliance costs are the costs of risk mitigation practices *over and above* the cost of current management practices. Using incremental compliance costs as an indicator of potential cost burden, the analysis examined impacts on individual facilities as a function of size. As in Section 3.7, this was performed using pro forma financial statements for three representative plant sizes. For the industry impact evaluation, the use of econometric models was considered and rejected for the same reasons discussed in Section 3.7. The industry-level analysis, therefore, focuses on the number of affected facilities and the magnitude of incremental compliance costs relative to the value of electricity sales.

Table 6-17. Cost Components Included in OCW Solid Settling Basin Designs

Category	Cost Components
Initial Capital Costs	Site development (access road, drainage ditch) Excavation Discharge structure Filter fabric 1' sand 2' clay liner Synthetic (HDPE) liner Leachate collection Synthetic liner for sludge drying basin Ground-water wells Indirect capital costs
Annual O&M Costs	Dredging Ash dewatering Operating and maintenance labor Electricity Offsite Subtitle D landfill ash disposal Environmental monitoring Leachate collection and treatment
Closure Costs	Pressure wash sludge drying basin Final ash dredging, dewatering and Subtitle D disposal 6" topsoil and vegetation 1.5' soil Leachate sampling Indirect closure costs

Table 6-18. Design Parameters Assumed for Small, Medium, and Large OCW SSBs

Parameter		SSB
Sizes (dry tons/year)	small medium large	36 172 923
Depth (feet)	small medium large	8.0 11.0 12.0
Area (acres)	small medium large	0.3 1.0 2.5

6.7.2 Incremental Compliance Cost

Key variables in estimating incremental compliance cost were the same as those discussed in Section 3.7.2. EPA's estimate of incremental compliance cost is some $1.7 million per year, using the most likely values for all the input variables. The potential range of annual incremental compliance costs is from $1.0 million to $3.5 million, allowing for uncertainty in the input variables.

Note that the costs above are incremental (above current costs). Annual costs were discounted at 7 percent to 1998 dollars, with no inflation built into out-year estimates. Also, it was presumed that compliance would be required immediately, and that amortization would take place over 40 years.

6.7.3 Compliance Cost Impact on Plants as a Function of Plant Size

As discussed in Section 3.7.3, this analysis does not include the potential impact of the ongoing restructuring of the utility industry and includes no analytical consideration of price effects.

Economic impacts at the plant level will depend on several major factors, including quantity of fuel used, quality of fuel, profitability, and production technology. To assess these impacts across the range of plants, EPA estimated financial data for model plants representing three size ranges: large (burning greater than 750,000 barrels of oil per year), medium (burning between 250,000 and 750,000 barrels of oil per year), and small (burning less than 250,000 barrels of oil per year). These model facilities are representative of publicly owned utilities. Table 6-19 compares incremental compliance costs to revenues and net income for these three model plants. The incremental compliance costs used in this analysis reflect EPA's best estimate based on most likely values of the relevant input variables.

Table 6-19. Plant-Level Impact of Incremental Compliance Costs

	Large Oil Plant Publicly Owned Utility		Medium Oil Plant Publicly Owned Utility		Small Oil Plant Publicly Owned Utility	
	$1,000's	Percent of Revenues	$1,000's	Percent of Revenues	$1,000's	Percent of Revenues
Revenues from Electricity	72,000	100%	18,000	100%	3,000	100%
Baseline Before Tax Net Income	6,480	***9.0%***	1,620	***9.0%***	210	***7.0%***
Expected Incremental Compliance Costs (replace unlined management unit with composite-lined unit)	43	0.1%	29	0.2%	12	0.4%
Expected Post-Compliance Net Income	6,437	***8.9%***	1,591	***8.8%***	198	***6.6%***

Thus, the incremental compliance cost for OCWs should not impact the financial viability of oil-fired plants. For a large publicly owned oil-fired plant generating about 1.2-billion kWh per year, costs would be expected to increase only $43,000 annually. This would increase costs by about 0.1 percent of annual revenue and thus reduce net income from 9.0 percent of revenue to 8.9 percent of revenue. Net income would thus be reduced from $6.48 million to $6.43 million per year.

Small and medium-sized oil-fired plants (generating from 50- to 300-million kWh per year) would be more significantly affected but still remain financially viable. Waste management costs would be in the range of $200 to $500 per dry ton; however, total compliance costs, as a percent of revenue, would climb about 0.2 to 0.4 percent only. Annual net income for these plants would decline about $12,000 to $29,000 per year, depending on the size of the plant. If such plants could increase prices to offset oil waste management costs, they would need only to increase from the representative baseline price of 6 cents per kWh to 6.02 cents per kWh to regain the pre-compliance position.

Table 6-20 shows how the estimated population of affected facilities breaks down by the three size categories represented by the model plants. It also compares the incremental compliance costs estimated for the model plants to average sales for individual plants in each size category. Based on this criterion, incremental compliance costs range from 0.1 to 0.4 percent of sales.

Table 6-20. Incremental Compliance Cost by Plant Size

Size Category	Number of Plants	Percent of Plants	Plant Sales ($ million/year)	Compliance Cost ($ million/year)	Percent of Sales
Large (>750,000 barrels/year of oil)	43	35%	$72	$0.04	0.1%
Medium (250,000 to 750,000 barrels/year of oil)	15	17%	$18	$0.03	0.2%
Small (<250,00 barrels/year of oil)	31	48%	$3	$0.01	0.4%

6.7.4 Industry Impacts

The electric power generating industry, including fossil fuel, hydroelectric, nuclear, and other fuel sources, was a $212 billion per year industry in 1996. Other economic characteristics of the electric utility industry are discussed in Section 3.7.4, along with information on the current restructuring of the U.S. electric power industry.

Based on the estimate of costs presented above, if OCWs were subject to risk mitigation alternatives, the electric utility industry would incur about $1.7 million in incremental annualized compliance costs. As shown in Table 6-21, this would represent less than one-tenth of 1 percent of the value of sales even if the oil-fired segment of the industry only is considered. Thus, the cost of compliance would be a very small percentage of revenues.

Table 6-21. Industry Economic Impacts, Oil Combustion Wastes

Industry Sales ($ billion/year)	Compliance Cost ($ billion/year)	Percent of Sales
$4.3	$0.002*	0.05%
* Rounded up from $1.7 million		

Because impacts as a percent of sales would be an order of magnitude less, oil-fired plants would have less need to pass through costs in the form of higher prices than would coal-fired plants if both were subject to risk mitigation alternatives. But again, the ability to pass through costs, even if quite modest, would be restricted by competition from unaffected plants.

6.8 FINDINGS AND RECOMMENDATIONS

6.8.1 Introduction

Based on the information collected for this Report to Congress, this section presents a summary of the Agency's main findings presented under headings that parallel the organization of this chapter. It then presents the Agency's tentative conclusions concerning the disposal and beneficial uses of comanaged wastes generated at facilities that burn oil.

6.8.2 Findings

Sector Profile

- There are about 177 utility and more than 2,000 non-utility facilities that burn oil. Oil-burning facilities are located throughout the United States, but utility facilities in particular are concentrated in the eastern United States and in California.

- Non-utilities burn oil for a variety of purposes, including production of manufacturing process steam, space heating, and captive power generation. They include industrial, commercial, and institutional facilities. They are located in diverse environments, including areas that vary widely in population density, geography, precipitation, and general climate.

- There is a declining trend of oil combustion, and the trend is expected to continue for the next two decades. While industrial combustion of oil is expected to grow modestly, it will be more than counterbalanced by gas turbine technologies replacing oil-fired utility steam-cycle processes.

Waste Generation and Characteristics

- Large-volume OCWs comprise primarily fly ash and bottom ash. Low-volume wastes associated with the burning of oil are similar in type and characteristics to those described previously for coal combustion, although comprehensive information on the amounts is not available. Examples of similar low-volume wastes at coal and oil combustors include boiler blowdown, ion exchange regeneration wastes, and boiler chemical cleaning waste.

- The utility sector generates an estimated 23,000 tons of OCWs annually. This is less than 0.1 percent of the quantity of coal combustion wastes generated by the utility sector.

- Comprehensive waste quantity information for the non-utility oil burning sector is not available. The Agency estimates that a maximum of 18,000 tons of OCWs are generated annually by the non-utility sector. Of this amount, the Agency estimates about 5,500 tons are collected; the remainder are released with stack gases. On average, this collected amount would equate to about 1 ton per year per boiler unit.

- The constituents of concern in OCWs are trace metal elements. No organic constituents, including dioxins, were identified at potential levels of concern in these wastes.

- OCWs only infrequently exhibit the RCRA toxicity characteristic. Six percent of the samples in the Agency's database exceeded the RCRA regulatory level for one or more of the eight RCRA metals. These sample were represented by 7 of the 40 sites in the database. The exceedences involved chromium, arsenic, cadmium, and selenium.

- Although not RCRA metals, both nickel and vanadium in whole waste and leachate are present at relatively high levels. Nickel and vanadium can range up to 4 percent and 20 percent, respectively, in the whole waste. These metals are naturally present in the source crude oil. Vanadium levels can be high enough in OCWs to make it economically feasible to process the wastes for recovery of vanadium.

- Based on the available data and engineering judgment, OCWs are not reactive, ignitable, or corrosive.

Waste Management Practices

- OCWs are managed alone by some facilities and are comanaged with low-volume wastes at other facilities. Utilities most often comanage oil fly ash with low-volume wastes in onsite impoundments (settling basins), and eventually transfer and manage the solids in landfills. Bottom ash is typically managed dry and placed in landfills.

- Settling basins used for onsite management are typically small, about 1 acre in size. Both concrete-lined basins and unlined percolation/evaporation basins are in use by the utility industry. The unlined basins are designed to discharge to ground water.

- Waste management survey information and anecdotal information suggests a recent trend toward the increased use of liners for impoundments.

- There are several beneficial uses of OCWs. These include vanadium recovery, use in concrete products, and use in structural fill materials. Comprehensive statistics do not exist on the total amounts of waste that are managed through beneficial uses.

Potential Risks and Damage Cases

- EPA conducted a risk assessment that found a lack of potential human health risk for most waste constituents. The Agency did identify potential human health risks via the ground-water pathway where these wastes are managed in unlined landfills and surface impoundments for arsenic (cancer), nickel (non-cancer), and vanadium (non-cancer). The identified risks are based on high-end risk scenarios in EPA's risk modeling analysis for human ingestion of well water influenced by release from the waste management unit. The time to reach the health-based level for arsenic in ground water at the receptor well ranges from 400 to 2,800 years. For nickel and vanadium, the times to reach the health-based levels are 50 years and 10 years, respectively.

- The Agency identified no potential human health risks via non-ground-water pathways.

- The Agency believes there is no significant ecological risk posed by the relatively small onsite surface impoundments and landfills used to manage these wastes.

- The Agency identified one damage case associated with management of these wastes, which involved elevated levels of cadmium. The release was basically confined to the vicinity of the facility and did not affect human receptors.

Existing Regulatory Controls, State, and Federal Requirements

- The utility industry, the sector that collects the majority of these wastes, has a significant level of installed environmental controls for managing these wastes. All of the identified landfills and about 60 percent of the impoundments used to manage these wastes are currently lined. The recent trend for utility facilities is toward liners and ground-water monitoring controls for these wastes.

- States have increasingly begun to impose controls on OCW management units. The majority of states have regulatory permit programs, as well as general authority to require siting controls, liners, leachate collection systems, ground-water monitoring, closure controls, daily or other operational cover, and fugitive dust controls for waste management.

- In a few states with significant generation of OCWs, newer landfills must have liners and other controls, but older landfills do not have to be retrofit with these controls.

- In a few states with significant generation of OCWs, there are no specific design requirements for surface impoundments used to store or manage these wastes. At least two of these states permit discharges to ground water from the impoundment units.

Potential Costs and Impact of Regulation

- The Agency estimates that the total annual incremental compliance costs for mitigation of the potential risks identified in this study (arsenic, nickel, vanadium by ground-water pathway) would be nearly $2 million (1998$). These costs represent replacement of existing unlined management units with lined management units, and implementing ground water monitoring and leachate collection and treatment. These measures do not represent implementation of full Subtitle C requirements, but rather modifications of such requirements that could potentially be adopted under Section 3004(x) of RCRA.

- If these wastes were to be regulated under full Subtitle C, virtually all existing facilities would be required to invest substantial funds and resources to modify existing management practices. The total annual cost of full Subtitle C requirements would considerably exceed the $2 million (1998$) estimate above.

- If beneficial uses of these wastes were subject to Subtitle C requirements, possibly all beneficial use practices and markets would cease.

6.8.3 Recommendations

Following are the Agency's recommendations for the wastes covered in this chapter. The recommendations are based on EPA's analysis of the eight Congressionally mandated study factors (Section 1.2). These conclusions are subject to change based on continuing information collection, continuing consultations with other government agencies and the Congress, and comments and new information submitted to EPA during the comment period and any public hearings on this report. The final Agency decision on the appropriate regulatory status for these wastes will be issued after receipt and consideration of comments as part of the Regulatory Determination, which will be issued within 6 months.

1. *The Agency is considering two approaches to address the potential risks that may be posed by disposal of these wastes. One approach would be regulatory using Subtitle C authority and the other would be to encourage voluntary changes in industry practices.*

The Agency found in many cases that OCWs, whether managed alone or comanaged with low-volume wastes, are seldom characteristically hazardous and may not present a significant risk to human health and the environment. These cases include situations in which the wastes are managed in lined units with adequate cover. The Agency believes that no significant ecological risks are posed by disposal of these wastes. Only one damage case was identified and it did not affect human receptors.

In light of the results of EPA's risk assessment, however, the Agency is concerned about situations in which the wastes are managed in unlined units, particularly comanagement in settling basins and impoundments that are designed and operated to discharge to ground water. As discussed in this chapter, the Agency's risk analysis suggests that three metals may pose potential ground-water pathway risks at such facilities: arsenic, nickel, and vanadium. While there is a trend in recent years to line new units and the Agency has anecdotal information that some facilities are preparing to either line or close their unlined units, the Agency has particular concerns with the high levels of nickel and vanadium in the wastes and in the leachate that is being discharged to ground water. The Agency's risk analysis identified high hazard quotients and short time periods to exceedence of health-based risk criteria at potential ground-water receptor locations for nickel and vanadium. The risks identified with these practices may be of sufficient concern to consider whether tailored regulations are necessary to target the potential risks. On the other hand, since the recent industry and state regulatory trends have been toward liners and ground-water monitoring for these waste disposal units, sufficient protection may be obtained by facilitating this trend and engaging the industry to voluntarily establish the appropriate controls. An example would be to line the existing unlined units and, where appropriate, to implement ground-water monitoring. The Agency solicits comment on its tentative conclusion, specific approaches that could be pursued to address these concerns, and the identification of only one damage case.

2. *The Agency has tentatively concluded that the existing beneficial uses of these wastes should remain exempt from Subtitle C.*

There are few existing beneficial uses of these wastes, which include components of cement, concrete, and construction fill as discussed in this chapter. No significant risks to human health exist for the identified beneficial uses of these wastes. This is based on one or more of the following reasons for each use: absence of identifiable damage cases, fixation of the waste in finished products which immobilized the material, and/or low probability of human exposure to the material. In the case of vanadium recovery operations, a valuable product is being produced; however, if the wastes resulting from the metal recovery processes are hazardous, they will be subject to the existing hazardous waste requirements.

Unlike coal combustion wastes, these wastes are not known to be used in minefill or agricultural applications. These wastes are not generated at rates high enough to justify their transport and use for filling mine voids. There are no known benefits to using these wastes for agricultural purposes.

7.0 NATURAL GAS COMBUSTION WASTES

Natural gas is the second most significant fossil fuel used by utilities in the United States. In 1996, gas-fired units accounted for approximately 20 percent of utility generating capacity, but only 9 percent of utility electricity generated. This generation rate represents a decline of 15 percent from the level reported in 1995 due in part to a substantial increase in the cost of gas in 1996. (Use of hydroelectric, oil-fired, and geothermal sources increased in 1996 to make up for the decrease in use of gas) (EIA, 1998a). Many gas-fired units are used to generate power during periods of peak demand. Figure 7-1 shows the locations of gas-fired power plants. Gas-fired units generate virtually no solid waste. Thus, although a significant portion of capacity is represented by gas combustors, this study does not include extensive analysis of natural gas combustors. The Agency intends to continue the exemption from Resource Conservation and Recovery Act (RCRA) Subtitle C for gas combustors.

Figure 7-1. Number of Gas-Fired Power Plants by State

7.1 TECHNOLOGY

As shown in Table 7-1, natural gas combustion accounts for a substantial fraction of both utility and non-utility generating capacity. Natural gas combustion technologies are similar to those used for oil combustion. In gas-fired steam electric boilers, gas is injected into the furnace in the presence of excess air. The same burner designs used for oil also are used to inject and combust natural gas. In fact, many combustion units can utilize either oil or gas. Unlike oil, natural gas does not require preparation (atomization) for mixing with combustion air (Stultz and Kitto, 1992). Because of its negligible ash

Table 7-1. Natural Gas-Fired Generating Capacity

Sector	Number of Gas-Fired Boilers	Gas-Fired Capacity (megawatts equivalent)	Total Sector Capacity (megawatts equivalent)	Percent Gas-Fired
Utility	788	104,961	469,272	22%
Non-Utility	6,907	46,663	148,021	32%
Total	7,695	151,624	621,884	24%

Because these capacity data are from different sources and different points in time, the percentages should be treated only as estimates.
Sources: EEI, 1994; EPA, 1990

content, combustion of natural gas generates virtually no solid waste; therefore, this study focuses primarily on coal-fired and oil-fired combustors.

7.2 FINDINGS AND RECOMMENDATIONS

As discussed above, combustion of natural gas generates virtually no solid waste; therefore, further analysis of the RCRA 8002(n) study factors is not warranted for gas fuels. EPA intends to continue the exemption from RCRA Subtitle C for gas combustors.

7.2.1 Introduction

Based on the information collected for this Report to Congress, this section presents a summary of the Agency's main findings presented under headings that parallel the organization of this chapter. It then presents the Agency's tentative conclusions concerning the wastes from burning natural gas.

7.2.2 Findings

Sector Profile

- There are nearly 800 gas-fired boilers in the utility sector that represent about 22 percent of utility power generating capacity.

- There are about 6,900 gas-fired boilers in the non-utility sector that represent about one-third of the non-utility power generating capacity.

Waste Generation and Characteristics

- There is virtually no solid waste that results from the combustion of natural (fossil fuel) gas.

7.2.3 Recommendations

Following are the Agency's recommendations for the wastes covered in this chapter. The recommendations are based on EPA's analysis of the eight Congressionally mandated study factors (Section 1.2). These conclusions are subject to change based on continuing information collection, continuing consultations with other government agencies and the Congress, and comments and new information submitted to EPA during the comment period and any public hearings on this report. The final Agency decision on the appropriate regulatory status for these wastes will be issued after receipt and consideration of comments as part of the Regulatory Determination, which will be issued within 6 months.

1. *The Agency has tentatively concluded that it will retain the Subtitle C exemption for natural gas combustors.*

The Agency has tentatively concluded that it will retain the Subtitle C exemption for natural gas combustors. The Agency solicits comment on whether it is appropriate to retain or remove the Subtitle C exemption for natural gas combustion since there are no solid wastes generated by the process.

REFERENCES

ACAA (American Coal Ash Association). 1996a. *State Solid Waste Regulations Governing the Use of Coal Combustion Byproducts (CCBs)*. June.

ACAA. 1996b. *Coal Combustion Byproduct (CCB) Production and Use: 1966–1994*. May.

ACAA. 1998. *1997 Coal Combustion Product (CCP) Production and Use*. September 10.

ASTSWMO (Association of State and Territorial Solid Waste Management Officials). 1996. *Non-Municipal, Subtitle D Waste Survey*. March.

CIBO (Council of Industrial Boiler Owners). 1997a. *CIBO Special Project on Non-utility Fossil Fuel Ash Classification Comparison Matrix and Questionnaire*. Spreadsheet database. January 3.

CIBO. 1997b. *Fossil Fuel Fluidized Bed Combustion By-Products Survey*. Electronic database. Council of Industrial Boiler Owners. November.

CIBO. 1997c. *Report to the U.S. Environmental Protection Agency on Fossil Fuel Combustion Byproducts from Fluidized Bed Boilers*. Prepared by the CIBO Special Project on Non-Utility Fossil Fuel Ash Classification and ICF Kaiser Consulting Group. November.

CIBO. 1998. *Fossil Fuel-fired Stoker Survey, Summary of Leaching Test Results.* Electronic report. August.

DOC (U.S. Department of Commerce). 1992. *Concentration Ratios in Manufacturing, (Tables 3 and 4)*. DOC, Economic and Statistics Administration. February.

DOC. 1994. *U.S. Industrial Outlook 1994*. DOC, International Trade Administration. January.

DOC. 1995a. *1992 Census of Manufacturers: Industry Series* (various standard industrial codes). DOC, Bureau of the Census. March-June.

DOC. 1995b. *1992 Census of Manufacturers, Industry Series*. DOC, Economic and Statistics Administration, Bureau of the Census. April.

DOC. 1995c. *Statistical Abstract of the United States, 1995*. DOC, Economic and Statistics Administration, Bureau of the Census. September.

DOE (U.S. Department of Energy). 1993. *Coal Combustion Waste Management Study*. Prepared for DOE, Office of Fossil Energy by ICF Resources Incorporated. February.

EEI (Edison Electric Institute). 1994. *Edison Electric Institute Power Statistics Database*. Electronic database.

EERC (Energy and Environmental Research Center). 1997. *IGCC and PFBC By-Products: Generation, Characteristics, and Management Practices.* 97-EERC-09-06. September.

EIA (DOE, Energy Information Administration). 1995a. *Electric Power Annual 1994, Volume II, (Operational and Financial Data)*. U.S. Department of Energy. DOE/EIA-0348(94)/2. November.

EIA. 1995b. *Financial Statistics of Major US Publicly Owned Electric Utilities 1994*. U.S. Department of Energy. DOE/EIA-0437(94)/2. December.

EIA. 1995c. *U.S. Electric Utility Demand-Side Management 1994*. U.S. Department Of Energy. DOE/EIA-0589(94). December.

EIA. 1995d. *Financial Statistics of Major US Investor-Owned Electric Utilities 1993*. U.S. Department of Energy. DOE/EIA-0437(93)/1. January.

EIA. 1995e. *Inventory of Power Plants in the United States 1994*. U.S. Department of Energy. DOE/EIA-0095(94). October.

EIA. 1996a. *Electric Power Monthly*. U.S. Department of Energy. DOE/EIA-0226(96/05). May.

EIA. 1996b. Annual Energy Outlook 1997 with Projections to 2015. U.S. Department of Energy. December 18.

EIA. 1996c. *Financial Statistics of Major U.S. Investor-Owned Electric Utilities 1995*. U.S. Department of Energy. DOE/EIA-0437(95)/1. December.

EIA. 1996d. *Electric Power Annual 1995, Volume II.* U.S. Department of Energy. DOE/EIA-0348(95)/2. December.

EIA. 1996e. The Changing Structure of the Electric Power Industry: An Update. U.S. Department of Energy. DOE/EIA-0562(96). December.

EIA. 1996f. *Cost and Quality of Fuels for Electric Utility Plants, 1996 Tables*. U.S. Department of Energy. May.

EIA. 1996g. *Electric Sales and Revenue, 1996, Summary*. U.S. Department of Energy.

EIA. 1997a. *Financial Statistics Major U.S. Publicly Owned Electric Utilities*. U.S. Department of Energy. June.

EIA. 1997b. *Electric Power Monthly (October).* U.S. Department of Energy. October.

EIA. 1997c. *Financial Statistics of Major U.S. Publicly Owned Electric Utilities 1995*. U.S. Department of Energy. DOE/EIA-0437(95)/2. June.

EIA. 1997d. *Electric Power Annual 1996, Volume I.* U.S. Department Of Energy. DOE/EIA-0348(96)/1. August.

EIA. 1997e. *Annual Energy Review 1997.* U.S. Department of Energy.

EIA. 1997f. *The Effects of Title IV of the Clean Air Act Amendments of 1990 on Electric Utilities: An Update*. U.S. Department of Energy, Office of Coal, Nuclear, Electric and Alternate Fuels. March.

EIA. 1998a. *Annual Energy Outlook 1999, with Projections to 2020*. U.S. Department of Energy, Office of Integrated Analysis and Forecasting. December.

EIA. 1998b. *Electric Power Monthly, Monthly Fuel Consumption*. U.S. Department of Energy.

EIA. 1998c. *Coal Industry Annual 1997*. U.S. Department of Energy.

EPA (U.S. Environmental Protection Agency). 1982. *Development Document for Effluent Limitations Guidelines and Standards and Pretreatment Standards for the Steam Electric Point Source Category*. Office of Water. EPA 44/1-82/029. November.

EPA. 1988. *Report to Congress: Wastes from the Combustion of Coal by Electric Utility Power Plants*. EPA/530-SW-88-002. Office of Solid Waste and Emergency Response. February.

EPA. 1989a. *Technical Background Supplement in Support of Rulemaking Adjustment Activities for Reportable Quantities (RQ) of Radionuclides*. Final Draft. Office of Radiation Programs. February.

EPA. 1989b. Risk Assessments. *Environmental Impact Statement for NESHAPs Radionuclides.* Volume 2. Office of Radiation Programs. EPA-520/1-89-006-1. September.

EPA. 1990. *U.S. EPA 1990 National Interim Emissions Inventory*. Electronic Database.

EPA. 1993a. *Report to Congress on Cement Kiln Dust*. Office of Solid Waste. December.

EPA. 1993b. *Supplemental Analysis of Potential Risks to Human Health and the Environment from Large-Volume Coal Combustion Waste*. July 30.

EPA. 1995a. *EPACMTP Users Guide*.

EPA. 1995b. *State Requirements for Industrial Non-hazardous Waste Management Facilities*. Office of Solid Waste, Municipal and Industrial Solid Waste Division. October.

EPA. 1995c. *Estimate of Health Risks Associated with Radionuclide Emissions from Fossil-Fueled Steam Electric Generating Plants*. Office of Radiation and Indoor Air. EPA/402/R-95/16. August.

EPA. 1996. *Preliminary Data Summary for the Steam Electric Point Source Category*. Office of Water. July.

EPA. 1997a. *National Biennial RCRA Hazardous Waste Report (Based on 1995 Data)*. Executive Summary. August.

EPA. 1997b. *Regulatory Impact Analysis for the Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule*. Office of Air Quality Planning and Standards, Innovative Strategies and Economics Group. July 17.

EPA. 1997c. *Fossil Fuel Electric Power Generation Sector Notebook*. September.

EPA. 1997d. *Fossil Fuel Combustion: Risk Comparison between the Utility and Non-Utility Industries*. Draft Report. Submitted to the Office of Solid Waste, prepared by Science Applications International Corporation, Reston, Virginia. October.

EPA. 1998a. *Characterization of Municipal Solid Waste in the United States: 1997 Update.* Office of Solid Waste, Municipal and Industrial Solid Waste Division. May.

EPA. 1998b. *Characterization of Construction and Demolition Debris in the United States.* Office of Solid Waste, Municipal and Industrial Solid Waste Division. June.

EPA. 1998c. *Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units – Final Report to Congress*. Volume 1. Office of Air Quality Planning and Standards. EPA-453/R-98-004a. February.

EPA. 1998d. *Technical Background Document for the Supplemental Report to Congress on Remaining Fossil Fuel Combustion Wastes: Ground-water Pathway Human Health Risk Assessment*. Revised Draft Final. Office of Solid Waste. June.

EPA. 1998e. *Non-groundwater Pathways, Human Health and Ecological Risk Analysis for Fossil Fuel Combustion Phase 2 (FFC2)*. Draft Final. Prepared for EPA by the Research Triangle Institute, Raleigh, North Carolina. April.

EPA. 1998f. *Fossil Fuel Combustion Waste Risk Assessment: Revised Groundwater Analysis and Sensitivity Results*. October.

EPA. 1998g. *Ecological Risk Assessment Guidelines*.

EPA. 1998h. *Technical Background Document: Beneficial Use of Fossil Fuel Combustion (FFC) Wastes*. Prepared by Science Applications International Corporation, McLean, Virginia. October.

EPRI (Electric Power Research Institute). 1987. *Inorganic and Organic Constituents in Fossil Fuel Combustion Residue, Volume 1: A Critical Review.* EP-5176. August.

EPRI. 1991. *Comanagement of Coal Combustion By-Products and Low-Volume Wastes: A Southeastern Site*. Final Report, EN-7545. Electric Power Research Institute. November, 1991.

EPRI. 1992. *Comanagement of Coal Combustion By-Products and Low-Volume Wastes: A Midwestern Site.* Interim Report, TR-100955. August.

EPRI. 1994a. *Calcium-Based Flue Gas Desulfurization Sludge Disposal Sites*. Final Report, TR-103914. Electric Power Research Institute. April, 1994.

EPRI. 1994b. *Sodium-Based Flue Gas Desulfurization Sludge Disposal Ponds*. Final Report, TR-103915. April.

EPRI. 1996a. *Comanagement of Coal Combustion By-Products and Low-Volume Wastes: A Southwestern Site*. Final Report, TR-105673. June.

EPRI. 1996b. *Evaluation of the Co-Management of High Volume Combustion By-Products with Other Utility Wastes: CL Site*. Revised Draft Report. December.

EPRI. 1997a. *Coal Combustion By-Products and Low-Volume Wastes Comanagement Survey*. Electronic Database. June.

EPRI. 1997b. *Coal Combustion By-Products and Low-Volume Wastes Comanagement Survey*. Draft Report. June.

EPRI. 1997c. *Evaluation of the Co-Management of High Volume Combustion By-Products with Other Utility Wastes: MO Plant*. Draft Report. April.

EPRI. 1997d. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Combustion By-products: AP Site*. Draft Report. June.

EPRI. 1997e. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Combustion By-products: SX Site*. Draft Report, TR001015. June 1997.

EPRI. 1997f. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Coal Combustion By-products: P4 Site*. Final Report, TR 108420. July.

EPRI. 1997g. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Coal Combustion By-products: OK Site*. Draft Report, TR 108421. July.

EPRI. 1997h. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Coal Combustion By-products: HA Site*. Draft Report. August.

EPRI. 1997i. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Coal Combustion By-products: FC Site*. Draft Report, TR 108425. August.

EPRI. 1997j. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Coal Combustion By-products: LS Site*. Final Report, TR 108422. August.

EPRI. 1997k. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Coal Combustion By-products: PA Site*. Final Report, TR 108427. August.

EPRI. 1997l. *Field Evaluation of the Comanagement of Utility Low-Volume Wastes with High-Volume Coal Combustion By-products: CY Site*. Final Report, TR 108426. August.

EPRI. 1997m. *Characterization of Byproducts from Coburning with Coal in Utility Boilers*. Draft Report. August.

EPRI. 1997n. *Oil Combustion By-Products Database*. Electronic database. July.

EPRI. 1998a. *Oil Combustion By-Products: Chemical Characteristics, Management Practices, and Groundwater Effects*. March.

EPRI. 1998b. *PCDDs and PCDFs in Coal Combustion By-Products (CCBS)*. Final Report. March.

EPRI. 1999. *Guidance for Comanagement of Mill Rejects at Coal-fired Power Plants*. Draft, TR-108994. January.

Elliott, Thomas, ed. 1989. *Standard Handbook of Power Plant Engineering*. New York: McGraw-Hill.

IEA (International Energy Agency Coal Research). 1996. *Confiring of Coal and Waste*. IEACR/90. August.

Morin, Roger A. 1994. *Regulatory Finance: Utilities' Cost of Capital*. Arlington, VA: Public Utilities Reports, Inc.

PUR (Public Utilities Reports, Inc.). 1994. *The Electric Industry in Transition*. Series of conference papers, June 14–15, Albany, New York.

Radian Corporation. 1988. *Assessment of NORM Concentrations in Coal Ash and Exposure to Workers and Members of the Public*. Prepared for the Utility Solid Waste Activities Group (USWAG). June.

R.S. Means. 1997. *Site Work and Landscape Cost Data*. 16th annual edition. R.S. Means Company, Inc., Kingston, Massachusetts.

R.S. Means. 1998a. *Environmental Remediation Cost Data – Assembles*. 4th annual edition. R.S. Means Company, Inc., Kingston, Massachusetts, and Delta Technologies Group, Inc., Englewood, Colorado.

R.S. Means. 1998b. *Environmental Remediation Cost Data – Unit Price*. 4th annual edition. R.S. Means Company, Inc., Kingston, Massachusetts, and Delta Technologies Group, Inc., Englewood, Colorado.

Stultz, S.C. and J.B. Kitto, eds. 1992. *Steam: Its Generation and Use*. Barberton, Ohio: Babcock & Wilcox.

USDA (U.S. Department of Agriculture). 1998. *Agricultural Uses of Municipal, Animal and Industrial Byproducts*. Conservation Research Report Number 4. January.

VDEQ (Virginia Department of Environmental Quality). 1994. *Cogeneration of Steam and Electric Power: Pollution Prevention Opportunities and Options*. Office of Pollution Prevention. September.

GLOSSARY*

ACAA – American Coal Ash Association.

air heater or **air preheater** – device that uses flue gases to preheat combustion input air.

air heater and precipitator washwater – wastes resulting from the periodic cleaning of the fireside (i.e., the side exposed to hot combustion products) of heat exchanging surfaces.

air monitoring system – periodic collection and analysis of air samples near a waste management unit.

alkalinity – the amount of carbonates, bicarbonates, hydroxides, and silicates or phosphates in a liquid. Reported as grains per gallon, pH, or parts per million of carbonate. Indicated by a pH of greater than 7.

anthracite – a hard black lustrous rank of coal (see coal rank).

APC – air pollution control.

ash – incombustible material in fuel that can become waste after combustion.

ash fusion temperature – the temperature at which a cone of coal or coke ash exhibits certain melting characteristics.

ASTM – American Society for Testing and Materials.

ASTSWMO – Association of State and Territorial Solid Waste Management Officials.

backfill – a project in which an excavation area is refilled with earth or other materials.

BACT – Best Available Control Technology under the Clean Air Act.

baghouse – an air pollution abatement device used to trap particulates by filtering gas streams through large fabric bags usually made of glass fibers.

baseload – that portion of electricity demand from a station or boiler that is practically constant for long periods.

baseload unit – an electrical generating unit that is used to supply baseload, and thus is operated continuously at an essentially constant rate.

BAT – Best Available Technology Economically Achievable under the Clean Water Act.

bed ash – spent bed material and fuel ash (bottom ash) that settle on the bottom of an FBC boiler.

bituminous coal – A common dense black rank of coal (see coal rank).

* References for this glossary include EIA, 1997d; EPA, 1988; CIBO, 1997c, and Stultz and Kitto, 1992.

BMP – best management practice under the Clean Water Act.

boiler – a closed vessel in which heat from an external combustion source (such as a fossil fuel) is transferred to produce hot water or generate steam.

boiler blowdown – waste generated by removal of a portion of boiler water for the purpose of reducing solid concentration or discharging sludge.

boiler chemical cleaning waste – waste resulting from the cleaning of boiler surfaces using chemical solutions.

boiler slag – melted and fused particles of ash that collect on the bottom of the boiler. Slag forms when operating temperatures exceed ash fusion temperature.

bottom ash – large ash particles that settle on the bottom of a boiler. Bottom ash does not melt and therefore remains in the form of unconsolidated ash.

BPT – Best Practicable Control Technology Currently Available under the Clean Water Act.

Btu – British Thermal Unit, a unit of heat energy.

bubbling fluidized bed system – a fluidized bed combustion system in which excess air passes through the bed in the form of bubbles. These systems have air velocities of 5 to 12 feet per second and larger bed particle size than circulating fluidized bed systems. These conditions result in a dense bed (45 pounds per cubic foot) with a well-defined surface.

Bunker C fuel oil – a residual fuel oil, also characterized as No. 6 fuel oil, which is used for commercial and industrial heating, electricity generation, and to power ships.

CAA – Clean Air Act.

CCW – coal combustion waste.

CERCLA – the Comprehensive Environmental Response, Compensation, and Liability Act, commonly referred to as Superfund.

CIBO – Council of Industrial Boiler Owners.

circulating fluidized bed system – a fluidized bed system that has high air velocities (as high as 30 feet per second) and fine particle sizes. As a result, the fluid bed is less dense (35 pounds per cubic foot) and has no well-defined top surface. Large quantities of bed material are recaptured from the gas stream and recirculated back to the furnace to maintain bed inventory.

CMTP – Composite Model for Leachate Migration with Transformation Products.

coal cleaning – the act of processing coal prior to combustion to change its characteristics (e.g., size, ash content, and/or sulfur content).

coal pile runoff – surface water runoff produced by precipitation falling on coal storage areas.

coal mill rejects – solid waste produced by onsite processing of coal in a mill prior to use.

coal rank – a system of classifying coal corresponding to its degree of metamorphism, geologic age, and heating value. Ranks include anthracite, bituminous, subbituminous, and lignite, with anthracite being the oldest and lignite being the youngest.

cogeneration – the production of electricity and another form of useful thermal energy (steam or hot water) from a single source.

combustion turbine (CT) – a system that uses exhaust from combustion (typically of oil or natural gas) directly to drive turbines.

compaction – the act of compacting waste after placement to reduce or prevent wind and water erosion of the waste and subsequent release to the environment.

condenser – a device that converts low-pressure steam back to water by transferring heat to a cooling water system.

cooling tower/cooling pond – recirculating cooling water system used to transfer heat picked up in the condenser to the atmosphere by evaporative cooling.

cooling tower basin sludge – solids that collect in the bottom of cooling towers and must be removed periodically and disposed.

cooling tower blowdown – water withdrawn from the cooling system in order to control the concentration of impurities in the cooling water.

corrosivity – see RCRA Subtitle C characteristics.

cover – a barrier placed on top of a waste management unit.

culm – refuse from the cleaning of anthracite coal.

CWA – Clean Water Act.

cyclone furnace – A combustion technology that creates a cyclone-like air circulation pattern causing smaller particles to burn in suspension, while larger particles adhere to a molten layer of slag that forms on the barrel walls.

demineralizer regenerant and rinses – see regeneration waste streams.

dioxin – general term for polychlorinated dibenzo-p-dioxins (PCDDs), a class of toxic chemicals.

distillate fuel oil – one of the petroleum fractions produced in conventional distillation operations. Included are products known as No. 1, No. 2, and No. 4 fuel oils.

dry scrubber – a flue gas desulfurization system in which the resulting byproduct is a dry, typically fine, powder.

dust suppression/control – conditioning waste with water or other liquid before and during transport and placement to prevent airborne transport of the waste and to reduce inhalation exposure to site workers.

economizer – a device for transferring heat from combustion exhaust to boiler input water.

EEI – Edison Electric Institute.

EEI database – 1994 EEI Power Statistics Database.

EIA – The U.S. Department of Energy's Energy Information Association.

electrostatic precipitator (ESP) – an air pollution control device that imparts an electrical charge to particulates in a gas stream, causing them to collect on an electrode.

EP – Extraction Procedure.

EPACMTP – EPA's Composite Model for Leachate Migration with Transformation Products.

EPRI – Electric Power Research Institute.

fabric filter – see baghouse.

FGD – flue gas desulfurization.

flue gas – the gaseous products of combustion that exit a boiler through a flue or stack.

flue gas desulfurization (FGD) technology – device that is used to remove sulfur oxides from flue gas after combustion.

flue gas desulfurization (FGD) waste – waste that is generated during the process of removing sulfur oxide gas from the flue gas after combustion.

fluidized bed combustion (FBC) – a combustion process in which fuel is burned on a bed of incombustible material (e.g., sand and limestone) while combustion air is forced upward at high velocities, making the particles flow as a fluid.

fly ash – suspended, uncombusted ash particles carried out of the boiler along with flue gases.

fossil fuel – a naturally occuring organic fuel, including coal, oil, and natural gas.

Furan – general term for polychlorinated dibenzofurans (PCDFs), a class of toxic chemicals.

generating unit – a combination of one or more boilers operated together to produce electricity or other useable thermal energy. May include one or more turbines, fuel processing systems, and/or air pollution control devices.

gigawatt (GW) – one billion watts.

gob – refuse from the cleaning of bituminous coal.

ground water monitoring system – one or several wells from which samples of ground water are periodically collected and analyzed.

HAP – Hazardous Air Pollutant under the Clean Air Act.

HDPE – high density polyethylene.

ignitability – see RCRA Subtitle C characteristics.

kilowatt (kW) – one thousand watts.

landfill – a facility or part of a facility in which wastes are placed for disposal in or on land.

leachate – the liquid resulting from water percolating through waste.

leachate collection system – a series of drains and tubing placed beneath a waste management unit, typically a landfill, that collect leachate for treatment or disposal.

lift – the depth of a cell in a landfill.

lignite – a brownish-black rank of coal (see coal rank).

lime – calcium oxide (CaO).

limestone – calcium carbonate ($CaCO_3$).

liner – a barrier placed underneath a landfill or on the bottom and/or sides of a surface impoundment.

MCL – maximum contaminant level.

mechanical collector – an air pollution control device that forces a cyclonic flow of the exit gas. This flow causes ash particles to be thrown against the walls of the collector and drop out of the gas.

megawatt (MW) – one million watts.

minefill – a project involving placement of fossil fuel combustion wastes in mine voids, whether for purposes of disposal or for beneficial uses such as mine reclamation.

monofill – a landfill that contains only one type of waste.

NAAQS – National Ambient Air Quality Standards under the Clean Air Act.

natural gas – a fossil fuel consisting of a mixture of hydrocarbon and nonhydrocarbon gases found beneath the Earth's surface.

NESHAP – National Emissions Standards for Hazardous Air Pollutants under the Clean Air Act.

No. 1 fuel oil – A light distillate fuel oil intended for use in vaporizing pot-type burners.

No. 2 fuel oil – A distillate fuel oil for use in atomizing-type burners for domestic heating or for moderate capacity commercial-industrial burner units.

No. 4 fuel oil – a fuel oil for commercial burner installations not equipped with preheating facilities. It is used extensively in industrial plants. This grade is a blend of distillate fuel oil and residual fuel oil stocks.

No. 5 fuel oil – a residual fuel oil of medium viscosity.

No. 6 fuel oil – a residual fuel oil used for commercial and industrial heating, electricity generation, and to power ships. Includes Bunker C fuel oil.

non-utility – for purposes of this study, an entity that combusts fossil fuel and whose primary commercial activity is not the production of electricity (see utility).

NPDES – National Pollution Discharge Elimination System under the Clean Water Act.

NSPS – New Source Performance Standards under either the Clean Water Act or Clean Air Act.

OCW – oil combustion waste.

particulates – fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in the air or emissions.

PCB – polychlorinated biphenyls, a class of toxic chemicals.

PCDD – polychlorinated dibenzo-p-dioxin.

PCDF – polychlorinated dibenzofuran.

PDWS – Primary Drinking Water Standards established by the Safe Drinking Water Act.

peakload – the maximum electricity demand from a facility or boiler that occurs during a specified period of time.

peakload unit or peaking unit – an electrical generating unit that is used to supply peakload, and thus is used intermittently during periods of high demand.

percolation basin – a surface impoundment in which liquids are allowed to discharge (percolate) into the ground.

petroleum coke – solid carbaceous residue remaining in oil refining stills after the distillation process.

PM – particulate matter.

pore water – interstitial water from borings of waste managed in surface impoundments.

POTW – Publicly Owned Treatment Works.

pozzolanic – forming a strong, slow-hardening cement-like substance when mixed with lime or other hardening material.

PSD – prevention of significant deterioration under the Clean Air Act.

PSES – Pretreatment Standards for Existing Sources under the Clean Water Act.

pulverized coal (PC) boiler or pulverizer – a combustion technology that burns finely ground coal in suspension.

PVC – polyvinyl chloride.

pyrites – iron sulfide (FeS_2) minerals that may oxidize during the combustion process to generate sulfur oxide gases. Pyrites may be a component of coal mill rejects.

RCRA – Resource Conservation and Recovery Act, as amended (Pub. L. 94-580). The legislation under which EPA regulates solid and hazardous waste.

RCRA Subtitle C characteristics – criteria used to determine if an unlisted waste is a hazardous waste under Subtitle C of RCRA.

> corrosivity – a solid waste is considered corrosive if it is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5, or if it is a liquid and corrodes steel at a rate greater than 6.35 millimeters per year at a test temperature of 55°C.
>
> toxicity – a solid waste exhibits the characteristic of toxicity if, after extraction by a prescribed EPA method, it yields a metal concentration 100 times the acceptable concentration limits set forth in EPA's primary drinking water standards.
>
> ignitability – a solid waste exhibits the characteristic of ignitability if it is a liquid with a flashpoint below 60°C or a non-liquid capable of causing fires at standard temperature and pressure.
>
> reactivity – a waste is considered reactive if it reacts violently, forms potentially explosive mixtures, or generates toxic fumes when mixed with water, or if it is normally unstable and undergoes violent change without deteriorating.

reactivity – see RCRA Subtitle C characteristics.

regeneration waste streams – wastes resulting from periodic cleaning of ion exchange beds used to remove mineral salts from boiler makeup water.

reinjection – the act of returning fly ash to a boiler to use any residual carbon content as fuel.

residual fuel oil – the heavier oils that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. Included are No. 5 fuel oil, Navy Special, and No. 6 fuel oil (which includes Bunker C fuel oil).

RIA – Regulatory Impact Analysis.

run-on and runoff control and collection system – Run-on controls prevent precipitation runoff from other parts of a site from reaching waste management areas. Runoff controls and collection systems prevent precipitation runoff from the waste management unit from being transported offsite.

scrubber – an air pollution control device used to remove particulates or contaminant gases from flue gas (see wet scrubber and dry scrubber).

SDWS – Secondary Drinking Water Standards established by the Safe Drinking Water Act.

SIC – Standard Industrial Classification.

SIP – State Implementation Plan under the Clean Air Act.

slag – molten or fused solid matter.

sluice water – liquid used to transport combustion waste or other material.

sluiced ash – combustion waste that has been transported using liquid.

slurry – a mixture of insoluble matter in a fluid.

SPLP – Synthetic Precipitation Leaching Procedure.

spray canal – recirculating cooling water system used to transfer heat picked up in the condenser to the atmosphere by evaporative cooling.

SSB – solids settling basin.

Standard Industrial Classification (SIC) code – a code developed by the U.S. government that categorizes businesses into groups with similar economic activities.

steam electric boiler – a system that combusts fuel in a boiler to produce steam, which in turn is used to provide heat or steam or drive turbines.

stoker – a combustion technology using a mechanically operated fuel feeding mechanism to distribute solid fuel over a grate for combustion.

subbituminous coal – an intermediate ranked coal between lignite and bituminous with more carbon and less moisture than lignite (see coal rank).

superheater – a device that follows a boiler and uses exhaust gases from combustion to raise the temperature of steam generated in the boiler.

surface impoundment – a facility that is a natural topographic depression, artificial excavation, or diked area formed primarily of earthen materials (although it may be lined with artificial materials), which is designed to hold an accumulation of liquid wastes containing free liquids.

surface water monitoring system – periodic collection and analysis of surface water samples near a waste management unit.

TCLP – Toxicity Characteristic Leaching Procedure.

toxicity – see RCRA Subtitle C characteristics.

TSS – total suspended solids.

UCCW – utility coal combustion waste.

unit – see generating unit or waste management unit.

USWAG – Utility Solid Waste Activities Group.

utility – a private or public organization that generates, transmits, distributes, or sells electricity. For purposes of this study, includes independent power producers regulated under the Public Utility Regulatory Policies Act (PURPA).

waste management unit – a structure, typically a landfill or surface impoundment, in which waste is placed for disposal or storage.

wastewater treatment sludge – waste generated from the treatment in settling basins or other treatment facilities of liquid waste streams.

water treatment sludge – waste resulting from treatment of makeup water for the steam cycle or for non-contact cooling.

watt – a unit of electrical power.

wet scrubber – a device utilizing a liquid, designed to separate particulate matter or gaseous contaminants from a gas stream by one or more mechanisms such as absorption, condensation, diffusion, or inertial impaction.