

## **Chapter 9**

### **Coal Combustion Residues and Mercury Control**

#### **9.1 Introduction**

The burning of coal in electric utility boilers generates residual materials including fly ash, bottom ash, boiler slag, and wet FGD scrubber solids/sludges. These residual materials are collectively referred to as “coal combustion residues” (CCRs). Currently, about 70 percent of the CCRs are land-disposed and the other 30 percent are reused or recycled for commercial uses such as production of wallboard, cement, and asphalt. Use of Hg emission control technologies on coal-fired electric utility boilers will probably increase the amount of Hg in certain types of CCRs, and could also change the composition and physical properties of these materials, possibly impacting their suitability for commercial reuse and recycling applications. Many of the potential retrofit Hg control technologies for coal-fired electric utility power plants discussed in Chapter 7 remove Hg from the flue gas and concentrate the captured Hg into CCRs (i.e., fly ash collected by PM control devices or solids/sludges generated by wet FGD scrubbers). Concern has been raised as to whether the Hg in the CCRs may later be re-released back to the environment.

A life-cycle evaluation is being conducted by NRMRL to help evaluate any potential environmental trade-offs and to ensure that there is not an increased environmental risk for the management of CCRs resulting from Hg control technologies. In support of this evaluation, the NRMRL is gathering data and information to assess future increases in Hg concentrations in CCRs resulting from application of Hg emissions control requirements to coal-fired electric utility boilers. This chapter summarizes some of the CCR information gathered by NRMRL to date and identifies the major data gaps and priorities of EPA’s research to ensure that Hg controlled at the coal-fired electric utility power plant stack is not later released from CCRs in an amount that is problematic for the environment.

#### **9.2 CCR Types**

The coal combustion process generates many different types of residues. At a given power plant, CCRs can be grouped as those generated on a continuous basis in high-volume quantities and those generated either continuously or intermittently in low-volume quantities. These low-volume CCRs include those resulting from maintenance and coal cleaning. However,

the focus of this chapter is on high-volume CCRs. High-volume CCRs include the bottom ash or slag removed directly from the boiler furnace and the fly ash collected by downstream PM control devices. For those coal-fired electric utility boilers using wet FGD scrubbers for SO<sub>2</sub> emissions control, large quantities of scrubber solid wastes and sludges are generated.

Nationwide quantities of high-volume CCRs generated in 1999 from coal combustion are available from data prepared by the American Coal Ash Association (ACAA).<sup>1</sup> Table 9-1 summarizes the characteristics and nationwide generation quantities for the major types of CCRs resulting from combustion of coal in power plants.

### **9.3 CCR Mercury Concentrations**

An initial review by NRMRL indicated that limited laboratory data were available on Hg concentrations in CCRs. Therefore, a nationwide Hg mass balance approach was taken to estimate Hg concentrations in CCRs. This Hg mass balance approach used data from the EPA Parts II and III ICR data bases on coal Hg concentrations and control device Hg capture efficiencies. The EPA ICR data were used with additional ACAA data on CCR generation rates, to estimate Hg concentrations in various CCRs. The Hg concentrations estimated with the nationwide mass balance approach are shown in Table 9-2. Table 9-2 shows calculated mean, 5<sup>th</sup> percentile, and 95<sup>th</sup> percentile values for Hg concentrations in CCRs. Mercury concentrations are projected to be highest in fly ash, with a mean value of 0.33 ppm, and a 95<sup>th</sup> percentile value of 1.2 ppm. Mercury concentrations in wet FGD scrubber solids/sludges are calculated to have a mean value of 0.20 ppm, and a 95<sup>th</sup> percentile value of 0.72 ppm. Mercury concentrations in bottom ash and boiler slag were calculated to be much lower, with mean values of 0.067 ppm, and 0.042 ppm, respectively.

Subsequent to performing the nationwide Hg mass balance to determine Hg concentrations in CCRs, more extensive laboratory data became available from the Electric Power Research Institute (EPRI) and the University of North Dakota Environmental and Energy Research Center (UND/EERC). A summary of available laboratory measurements of Hg in CCRs is shown in Table 9-3. The laboratory measurements in Table 9-3 generally show good correlation with the nationwide mercury mass balance predictions in Table 9-2. For example, the EPRI fly ash data (382 samples) have a mean mercury concentration of 0.44 ppm, with a 95<sup>th</sup> percentile value of 1.13 ppm, and the UND/EERC data (20 samples) have a mean Hg concentration of 0.22 ppm, and a 95<sup>th</sup> percentile value of 1.03 ppm. Both these sets of data correlate well with fly ash calculations obtained by the nationwide Hg mass balance, which indicates a mean concentration of 0.33 ppm, and 95<sup>th</sup> percentile value of 1.2 ppm.

### **9.4 Nationwide Management Practices**

A summary comparison of the quantities and management techniques for various CCRs is presented in Figure 9-1. The CCRs are either land-disposed (in a monofill or surface

**Table 9-1. Coal combustion residues.**

<b>Coal Combustion Residue</b>	<b>Description</b>	<b>Average Quantity Generated Per Ton of Coal Burned <sup>a</sup></b>	<b>Total Nationwide Quantity Generated in 1999 <sup>b</sup></b>
Fly ash	Fine, powdery non-combustible mineral matter in the boiler flue gas and collected by electrostatic precipitator or fabric filter	160 lb/ton	63,000,000 tons
Bottom ash	Dark gray, granular, porous non-combustible mineral matter heavier than fly ash and collected in bottom of the boiler furnace.	40 lb/ton	17,000,000 tons
Boiler slag	Coarse, black, glassy mineral matter that forms when molten bottom ash contacts quenching waters in wet-bottom furnaces.	100 lb/ton	3,000,000 tons
Wet FGD scrubber solids/sludges	Solid material or sludge generated by scrubbing processes used to remove sulfur from the flue gases.	350 lb/ton	25,000,000 tons

(a) Source: Reference 2.

(b) Source: Reference 1.

**Table 9-2. Calculated Hg concentrations in CCRs using EPA ICR data.**

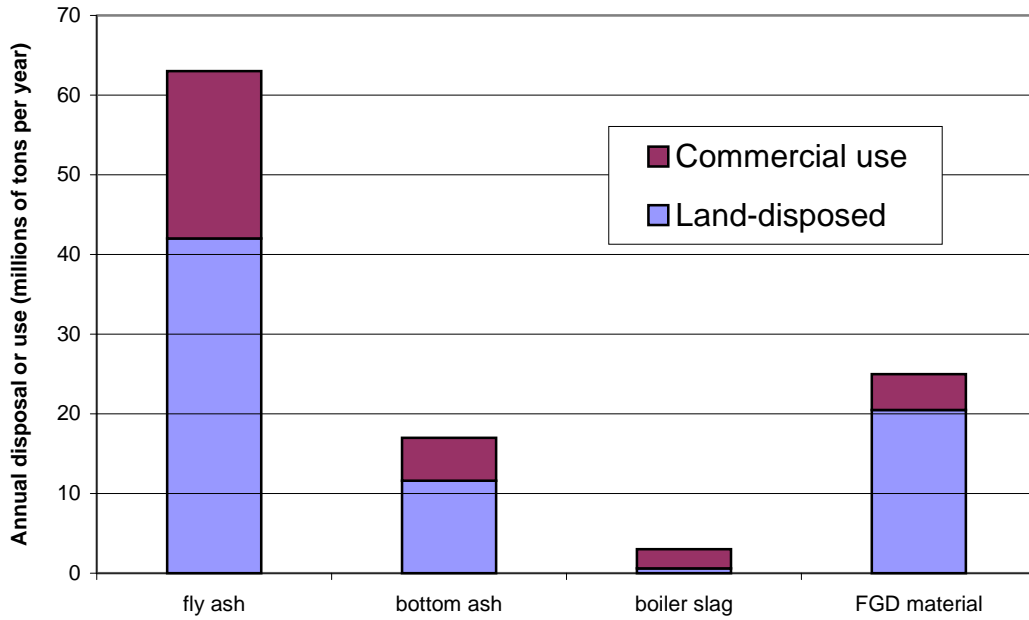
<b>Coal Combustion Residue</b>	<b>Hg Concentration (ppm) <sup>a</sup></b>		
	<b>5th Percentile</b>	<b>Mean</b>	<b>95th Percentile</b>
Fly ash	0.062	0.33	1.2
Bottom ash	0.019	0.067	0.16
Boiler slag	0.012	0.042	0.10
Wet FGD scrubber solids/sludges	0.038	0.20	0.72

(a) Changes in Hg control technology requirements for coal-fired electric utility power plants will cause changes in the Hg concentration in fly ash and wet FGD scrubber solids/sludges.

**Table 9-3. Summary of available test data on Hg concentrations in major types of CCRs.**

Coal Combustion Residue	Test Data Source (Reference)	Number of Samples	Hg Concentration (ppm)					
			Min.	5 <sup>th</sup> Percentile	Median	Mean	95 <sup>th</sup> Percentile	Max.
Fly ash	EPRI (Reference 3)	382	0.0002	0.0002	0.09	0.44	1.13	27.7
	UND/EERC (Reference 4)	20	<0.002	0.002	0.076	0.22	1.03	1.24
	EPA (Reference 5) (fine fly ash)	n.r. <sup>a</sup>	0.005	n.r.	0.10	n.r.	n.r.	2.50
	EPA (Reference 5) (mechanical hopper)	n.r.	0.008	n.r.	0.073	n.r.	n.r.	n.r.
	EPA (Reference 5) (1993 data)	n.r.	0.013	n.r.	0.10	n.r.	n.r.	n.r.
Bottom ash	EPA (Reference 5)	12	0.003	n.r.	0.009	n.r.	n.r.	0.040
	EPA (Reference 6) (combined bottom ash and slag)	n.r.	0.005	n.r.	0.023	n.r.	n.r.	4.2
Boiler slag	EPA (Reference 5)	12	0.005	n.r.	0.023	n.r.	n.r.	4.2
Wet FGD solids/sludges	EPA (Reference 5)	15	0.073	n.r.	4.8	n.r.	n.r.	39.0

(a) n.r. = not reported.



**Figure 9-1. Nationwide CCR management practices in the year 1999 (source: graph prepared using data from Reference 1).**

impoundment) or are being used for commercial applications. In the United States in the year 1999, approximately 110 million tons of CCRs were generated. Approximately one-third (31 percent) of these materials were reused or recycled in various commercial uses, with the remainder being land-disposed.

#### ***9.4.1 Reuse and Recycling of CCRs***

The primary commercial uses of CCRs are listed in Table 9-4. The table presents how each of four types of high-volume CCRs were used for commercial application in 1999. The use of fly ash as a replacement ingredient for concrete or grout is the most common use for any CCR. In this application, the fly ash can serve as a replacement for sand or as a partial replacement for Portland cement in the concrete mix. Significant amounts of fly and bottom ash are used for structural fills (e.g., creation of highway embankments). The addition of CCR to form a road base allows for greater long-term strength development than conventional materials. Bottom ash is used as a substitute for salt for road de-icing operations. Almost all of the boiler slag generated in 1999 was used as blasting grit or roofing granules. Wet FGD scrubber solid wastes and sludges that do not contain high levels of fly ash can be used either directly or, with additional processing, in the production of gypsum wallboard. The substitution of wet FGD scrubber solids/sludges for natural gypsum in wallboard manufacturing has been growing rapidly.

For some commercial uses of CCRs, there is concern regarding the potential re-release of Hg, particularly for those uses involving high-temperature processes. In cement manufacturing, for example, the high temperatures in the cement kiln will revolatilize the Hg contained in the coal fly ash that is used as a material substitute. Questions exist regarding the fraction of Hg in the fly ash that may be emitted when fed to a cement kiln. Other commercial processes that expose CCRs to elevated temperatures include wallboard manufacturing (during the drying process) and when CCRs are used as fillers in asphalt.

For some of the other commercial uses, it appears unlikely that significant Hg in CCRs would be re-introduced into the environment. For example, Hg is unlikely to be re-volatilized or leached from concrete, flowable fill, or structural fill. However, the various commercial uses will be evaluated to determine if there is any significant increase in environmental risk as a result of changes occurring to CCRs.

#### ***9.4.2 Land-disposal of CCRs***

There are currently approximately 600 waste disposal units (monofills or surface impoundments) being used for disposal of CCRs from electric utility coal-fired electric utility power plants in the United States.<sup>5</sup> The monofills used for these residues may be located either on-site at the power plant or off-site. Surface impoundments are almost exclusively located at the power plant site. While the distribution of units presently is about equal between monofills and surface impoundments, there is an increased trend to use monofills as the primary disposal method.

**Table 9-4. Commercial uses for CCRs generated in 1999 (source: data from Reference 1).**

Commercial Application or Use	Coal Combustion Residue								Nationwide Total (tons)
	Fly ash		Bottom ash		Boiler slag		Wet FGD solids/sludges		
	tons	%	tons	%	tons	%	tons	%	
Concrete/grout	10,000,000	49	700,000	13	11,000	0.5	290,000	6.5	11,000,000
Waste stabilization/solidification	1,900,000	9.3	69,000	1.3	0	0	16,000	0.4	2,000,000
Structural fill	3,200,000	15	1,400,000	26	52,000	2.2	580,000	13	5,200,000
Mining applications	1,500,000	7.3	150,000	2.8	10,000	0.4	230,000	5.2	1,900,000
Raw feed for cement clinker	1,300,000	6.1	160,000	2.9	0	0	0	0	1,500,000
Road base/subbase	1,200,000	5.9	1,100,000	20	5,500	0.2	17,000	0.4	2,300,000
Flowable fill	850,000	4.1	13,000	0.2	0	0	0	0	860,000
Other	460,000	2.2	450,000	8.3	76,000	3.2	180,000	4.1	1,200,000
Mineral filler	160,000	0.8	63,000	1.2	12,000	0.5	0	0	240,000
Soil modification	78,000	0.4	17,000	0.3	13,000	0.5	2,100	<0.1	110,000
Agriculture	78,000	0.4	43,000	0.8	0	0	80,000	1.8	200,000
Snow and ice control	3,200	0.1	1,100,000	20	51,000	2.2	0	0	1,200,000
Blasting grit/roofing granules	0	0	160,000	2.9	2,100,000	90	0	0	2,300,000
Wallboard	0	0	0	0	0	0	3,100,000	69	3,100,000
Nationwide Total <sup>a</sup>	21,000,000	100	5,400,000	100	2,300,000	100	4,500,000	100	33,000,000

(a) Sum of individual values may not equal total due to rounding.

On May 22, 2000, the EPA made the regulatory determination that the disposal of CCRs does not warrant regulation under subtitle C of RCRA and retained the hazardous waste exemption for these materials provided under RCRA section 3001(b)(3)(C).<sup>7</sup> However, the EPA also determined that national regulations under subtitle D of RCRA are warranted for CCRs when they are disposed of in landfills or surface impoundments, and that regulations under subtitle D of RCRA [and/or possibly modifications to existing regulations established under authority of the Surface Mining Control and Reclamation Act (SMCRA)] are warranted when these materials are managed in surface or underground mines. The national regulations will apply to disposal of coal combustion wastes that are generated at electric utility and independent power producing facilities and managed in surface impoundments, landfills, and mines.

The EPA will re-evaluate the risk posed by managing coal combustion residues if levels of Hg or other hazardous constituents change due to any future Clean Air Act air pollution control requirements for coal burning utilities. When any rulemaking under the Clean Air Act proceeds to the point where an assessment of the likely changes to the character of CCRs is completed, EPA will evaluate the implications of these changes relative to existing or planned national RCRA regulations governing these materials and take appropriate action.

## **9.5 Current Status of CCR Research Activities**

The EPA/NRMRL is preparing a report on characterization and management of CCRs from coal-fired electric utility power plants. The report examines changes in the Hg content of CCRs that potentially could occur as the result of implementing different control technologies to reduce stack emissions of Hg from coal-fired electric utility power plants. This report is scheduled to be published in the near future.

Test methods to characterize CCRs and to determine Hg volatilization and leaching from CCRs in various management practices are being reviewed by EPA/NRMRL. The goal of this review is to ensure that leaching and volatilization testing conducted by all parties, inside and outside of the EPA, is uniform and appropriate.

Multiple-site, full-scale field test programs are currently being conducted under a DOE/NETL cooperative agreement to obtain performance and cost data for using different Hg control technologies to reduce Hg emissions from existing coal-fired electric utility power plants (discussed in Chapter 7). As part of these test programs, field data are being collected that will help determine changes in the Hg content of CCRs as a result of implementing these Hg controls technologies. In addition, CCR commercial applications requiring elevated temperature processes, such as cement manufacturing and wallboard production, are being evaluated to determine the amount of Hg revolatilization that occurs, and the impacts of this revolatilization on the environment.

The EPA/NRMRL is planning to prepare a report, scheduled for publication in 2003, presenting data and other information relating to changes to CCRs as a result of implementing

different Hg control technologies. This report will also help identify any potential concerns due to increased environmental risk from the management of CCRs resulting from Hg control measures.

## 9.6 Future CCR Research Activities and Needs

Coordination with industry and others will continue to identify available data and information that will help to characterize any changes to CCRs as a result of Hg control measures. Different methods are being used to characterize CCRs which result in data of questionable value. The EPA ORD/NRMRL is working closely with EPA/OSW to identify methods for characterizing CCRs to identify potential changes to CCRs as a result of Hg control measures.

Samples of the resulting CCRs from the on-going full-scale field test programs of different Hg control technologies will be collected to characterize the resulting CCRs and to identify any changes occurring to CCRs that would increase environmental risk from waste management and potential commercial applications.

Questions regarding the potential release of Hg from land-disposal result in the need to conduct field test measurements to ensure that Hg is not being emitted through either biological processes or leaching. Opportunities will be identified to help address questions regarding any increased environmental risk due to changes occurring to CCRs.

Questions also exist relating to CCRs being used in high-temperature processes such as cement manufacturing and wallboard production. Effort is needed to determine the amount of Hg that may be released during the manufacturing process and other life-cycle stages, including final disposal in a landfill.

## 9.7 References

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