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Comparison of Coal Combustion Products to Other Common Materials

Chemical Characteristics

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2 DATA AND METHODS

Summaries of all concentrations used for comparison in this study are listed in Tables 2-1 and 2-2. Data sources for materials other than CCPs are discussed in sections of the report where data are compared.

Coal combustion product data were obtained primarily from the CP-Info database (EPRI, 2009a). Where data were not available in CP-Info, data were obtained from the EPRI PISCES database (EPRI, 2009b). The CP-Info and PISCES databases contain results generated during 30 years of EPRI research and represent a broad range of CCP materials. Reports used to compile data for CP-Info include:

- EPRI, 1986. *Mobilization and Attenuation of Trace Elements in an Artificially Weathered Fly Ash.* EPRI, Palo Alto, CA. EA-4747.
- EPRI, 1987. *Matrix Isolation Spectroscopy and the Stability of Polycyclic Aromatics in Coal Ash: Final Report.* EPRI, Palo Alto, CA. EA-5148.
- EPRI, 1987. *Chemical Characterization of Fossil Fuel Combustion Wastes.* EPRI, Palo Alto, CA. EA-5321.
- EPRI, 1994. *A Field and Laboratory Study of Solute Release from Sluiced Fly Ash.* EPRI, Palo Alto, CA. TR-104585.
- EPRI, 1995. *Effects of Flue Gas Desulfurization (FGD) System Additives on Solid By-Products.* EPRI, Palo Alto, CA. TR-102367.
- EPRI, 1996. *Mixtures of a Coal Combustion By-Product and Composted Yard Wastes for Use as Soil Substitutes and Amendments.* EPRI, Palo Alto, CA. TR-106682.
- EPRI, 1999. *Utilization of Coal Combustion By-Products in Agriculture and Land Reclamation.* EPRI, Palo Alto, CA. TR-112746.
- EPRI, 2002. *Mercury Releases from Coal Fly Ash.* EPRI, Palo Alto, CA. 1005259.
- Gustin, M. and Ladwig, K., 2004. *An assessment of the significance of mercury release from coal ash.* Journal of the Air and Waste Management Association 54(320-330).
- EPRI, in preparation. *FGD Gypsum Characterization Data.* EPRI, Palo Alto, CA. Scheduled for publication in 2010.

In many studies, multiple CCP sample analyses originate from a single power plant. This created the potential for biasing the dataset, overweighting results produced from a single plant. In the current investigation, results known to originate from a single plant were averaged to produce a single concentration for that plant site. This concentration was then used in subsequent statistical calculations. Although this approach limited the number of data points available for analysis, it achieved a more representative sampling across the electric utility industry without biasing results from one plant.

In this report, the following statistical values are used: median, minimum, maximum, 10th percentile, and 90th percentile. Median values are also known as the 50th percentile, or data point at which half the values fall below and half fall above. Minima and maxima are the smallest and largest data points in the dataset, respectively. Where possible, the 10th and 90th percentile values were used as better representations of data ranges, due to the possibility of outlier data. In some cases, percentile values were not calculated, due either to lack of data or to the high potential for bias in the dataset. In the case of metal slags, there were not enough data reported to calculate percentages. In the case of fertilizers, the very large variability in reported fertilizer type and manufacturers made percentile calculations less reliable than a comparison of minima and maxima.

In many cases, some or all statistical values were less than method detection limits. In these cases, the detection limit was substituted as the value for that statistic. Ranges are non-existent for the cases where all values are less than detection limits, and are represented graphically as single points or bars. In the case of cadmium in fly ash, the dataset contained a few detection limits higher than most of the detected values. In this case, all non-detects higher than the median of detects were excluded.

Data are presented using bars representing the concentration range of the CCP plotted against the concentration range of the material being compared. Graphically, using a log scale allows plotting of multiple elements on one graph, maintaining the ability to visually compare concentration ranges. The bars are bounded by 10th and 90th percentiles, or by minima and maxima. Elements are then qualitatively grouped into one of seven categories, depending upon how the CCP concentration range compares graphically to the selected material.

Table 2-1
Statistical summary of the concentrations of various elements in coal combustion products (all concentrations in mg/kg)

Fly Ash		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Sb	Be
	# Sites	59	39	28	59	58	19	59	36	38	229
	Max	1385	10850	17	651	2120	1.3	47	13	131	826
	90th Perc.	261	5064	6.2	298	143	0.5146	18	7.6	16	26
	50th Perc.	71	923	1.07	133	49	0.1075	11	<4.9	<7.2	10.6
	10th Perc.	22	381	0.36	27	21	0.0104	1.8	<4.9	<7.2	2.2
	Min	8.1	239	<0.11	11	13	<0.0025	<1.4	<4.9	<7.2	<0.4
		B	Co	Cu	Mn	Ni	Tl	V	Zn	Fe	Mo
	# Sites	26	3	57	49	57	59	39	59	66	57
	Max	2500	124	1452	1332	353	85	652	2880	175550	236
	90th Perc.	1018	101	216	700	231	45	364	683	128838	60
	50th Perc.	322	7.9	140	189	102	2.4	254	152	69100	19
	10th Perc.	118	7.4	62	91	47	<0.17	59	63	33575	9.0
	Min	55	7.3	45	44	23	<0.17	<43.5	25	17000	4
Bottom Ash		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Sb	Be
	# Sites	37	37	37	37	37	160	37	37	37	152
	Max	56	9360	<5.5	4710	843	1.3	8.2	7.5	8.4	568
	90th Perc.	21	3604	<5.5	1132	53	0.080	4.2	<5.5	<7	14
	50th Perc.	7.2	768	<5.5	191	20	0.018	<1.25	<5.5	<7	5.8
	10th Perc.	2.6	378	<5.5	51	8.1	0.004	<1.25	<5.5	<7	0.208
	Min	<1.3	<61	<5.5	<24	<2.1	<0.002	<1.25	<5.5	<7	<0.064
		B	Co	Cu	Mn	Ni	Tl	V	Zn	Fe	Mo
	# Sites	76	NA	37	37	37	21	37	37	37	37
	Max	990	NA	146	1940	1267	59	275	717	199500	46
	90th Perc.	335	NA	118	892	445	0.88	250	367	158850	27
	50th Perc.	82	NA	73	262	123	<0.5	161	59	101200	11
	10th Perc.	2.7	NA	39	85	39	<0.5	<50	16	40339	3.9
	Min	<2.04	NA	20	73	<12	<0.5	<50	3.8	21600	<1.4
FGD Gypsum		As	Ba	Cd	Cr	Pb	Hg	Se	Ag	Sb	Be
	# Sites	27	27	26	27	27	27	27	1	26	27
	Max	11	55	0.37	24	2.0	1.5	32	<4.9	2.0	<0.1
	90th Perc.	5.9	22	0.21	6.7	<1	0.801	24	<4.9	<0.4	<0.1
	50th Perc.	2.9	6.1	0.07	2.4	<1	0.200	4.2	<4.9	<0.4	<0.1
	10th Perc.	2.1	2.6	<0.02	0.83	<1	0.035	<2.5	<4.9	<0.4	<0.1
	Min	<1.9	0.91	<0.02	0.60	<1	0.0075	<2.5	<4.9	<0.4	<0.1
		B	Co	Cu	Mn	Ni	Tl	V	Zn	Fe	Mo
	# Sites	26	26	26	27	26	26	26	26	26	26
	Max	387	<1	3.2	129	2.4	<0.05	8.6	23	1823	3.1
	90th Perc.	93	<1	2.2	47	2.1	<0.05	4.1	14	1611	1.7
	50th Perc.	<25	<1	1.1	8.8	1.1	<0.05	<1	5.4	800	0.53
	10th Perc.	<25	<1	<0.4	<1	0.6	<0.05	<1	<1.25	296	0.17
	Min	<25	<1	<0.4	<1	<0.2	<0.05	<1	<1.25	130	<0.02

NA – Data Not Available

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SOILS

Information Sources

Two primary sources of soil composition data exist for the United States:

- United States Geological Survey (Shacklette and Boerngen), 1984. *Element concentrations in soils and other surficial materials of the coterminous United States: An account of the concentrations of 50 chemical elements in samples of soils and other regoliths.* U.S. Geological Survey Professional Paper 1270.
- United States Geological Survey (Smith et al.), 2005. *Major- and trace-element concentrations in soils from two continental scale transects of the United States and Canada.* U.S. Geological Survey Open-File Report 2005-1253.

The choice of dataset used for comparison is discussed in detail below.

Comparison of Soil Data Sources

Each study proposed to establish "baseline" soil concentrations across the United States. USGS (1984) accomplished this by sampling surface soils across the entire coterminous United States, but at a relatively low sampling density (shown as circles in Figure 4-1). USGS (2005) sampled soils along two transects (North-South and East-West), but at a higher sampling density (shown as solid line transects in Figure 4-1). The following discussion describes advantages and disadvantages to using either study as a primary data source, without rigorous statistical analysis of the data.

The benefits of using USGS (1984) as the primary dataset are:

- The study sampled more total sites (1,323) than USGS (2005) (265). More data provide greater confidence for calculations, and it is more likely that the dataset will capture the total concentration range for a particular element. For example, the highest arsenic concentration in the USGS (2005) dataset is 23 mg/kg, compared to 97 mg/kg in the USGS (1984) study;
- The study included more elements (50) than the USGS (2005) study (42);
- Sample locations were spread across the entire coterminous United States, providing more coverage of factors that influence soil development and chemistry—specifically time, climate, topography, and parent materials (rocks). For example, USGS (2005) appears to entirely neglect volcanic soils, and may focus too heavily on prairie soils (Figure 4-2);
- The study included boron, a commonly found element in CCPs, but USGS (2005) did not;