TRACE ELEMENTS IN COAL: A USGS PERSPECTIVE OF THE CLEAN AIR ACT

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INTRODUCTION

The provisions of the 1990 Clean Air Act Amendments require the U.S. Environmental Protection Agency (EPA) to evaluate the hazards to public health resulting from emissions by electric utility steam-generating plants. Among the substances listed in the Act as hazardous air pollutants are about a dozen elements found in coal (As, Be, Cd, Co, Cr, Hg, Mn, Ni, Pb, Sb, Se, and U). Coal combustion can be a primary anthropogenic source for some of these elements (especially Be, Co, Hg, Sb, Se).

There is no publicly available data base that contains comprehensive information on the trace element content of coal beds that are used for combustion. Therefore, the EPA has chosen the U.S. Geological Survey (USGS) Coal Quality Data Base to use in their evaluation of the impact of coal switching and to estimate the trace element input load to electric utility steam generating plants.

THE USGS COAL QUALITY DATA BASE

The USGS Coal Quality Data Base is an interactive, computerbased data base. It contains comprehensive analyses of more than 13,000 samples of coal and associated rocks from every major coal-bearing basin and coal bed in the United States and about 1,000 analyses of coal samples from other countries. The data in the Coal Quality Data Base represent analyses of the coal **as it exists in the ground.** The data commonly are presented on an as-received whole-coal basis.

SAMPLE COLLECTION AND ANALYTICAL PROTOCOL

The recommended procedures for collecting samples for analyses that were included in the data base are described by Stanton (1). Detailed information on the geographic location (State, county, longitude and latitude, mine, etc.) and geologic and stratigraphic information (thickness, depth, geologic age, formation, member, bed, etc.) are recorded for each sample.

Coal and associated rock samples were analyzed for the concentrations of approximately 75 major, minor, and trace elements (2) by the USGS, and for the standard coal characteristics by the U.S. Bureau of Mines and commercial testing laboratories using American Society of Testing and Materials standards (3). The standard coal characteristics include proximate and ultimate analysis, calorific value, forms of sulfur, ash-fusion temperatures, free-swelling index, and air-drying loss. Equilibrium moisture, apparent specific gravity, and Hardgrove Grindability Index are determined on selected samples. A total of 136 parameters are determined for each sample.

NATURE OF THE COAL QUALITY DATA BASE

The samples collected and submitted for analysis and inclusion in the data base consist primarily of full bed core and channel samples. Some of the bed samples were collected in benches or in measured intervals of the bed. The bench or interval analyses can be weighted by thickness and composited to obtain a calculated analysis of the full coal bed. Where possible, clastic rocks (partings, overburden, underburden) associated with the coal bed also were collected and analyzed.

Finkelman and others (4) compiled a bibliography of publications containing element data from the Coal Quality Data Base. This report also contains the number of analyzed samples for each State and the number of those analyses that have been published. Approximately half of the data in the data base has been included in publications.

During the past 5 years an additional 500 analyses have been added to the data base. About 75 percent of the samples were collected and analyzed prior to 1982. In some basins, many of the coal samples were collected from active surface and underground mines. In some of these areas, mining is no longer active. Nevertheless, the data from these areas are still useful for regional projections of coal quality variation.

The addition of coal quality data from the Illinois Geological Survey (approximately 700 analyses) and from the New Mexico Bureau of Mines and Geology (approximately 550 analyses) will enhance the Coal Quality Data Base.

VERTICAL AND LATERAL VARIATIONS OF THE COAL QUALITY DATA

One of the more common uses of the USGS coal quality data is to evaluate vertical and lateral distribution of coal quality parameters. Table 1 contains arithmetic means for the potentially hazardous air pollutants in several coal basins (data for all tables are from reference 5). Several elements exhibit a wide range of concentrations among the coal basins; for example, cadmium ranges from 0.1 ppm in the Appalachian basin to 4.2 ppm in the Interior Coal Province. In contrast, mercury ranges from 0.12 ppm in the Powder River basin to only 0.22 ppm in the Gulf Coast Province.

Table 2 contains arithmetic means of the potentially hazardous air pollutants in six coal beds within the Appalachian basin. Mercury and antimony show a greater range within the coal basin than among coal basins. Table 3 contains arithmetic means for the potential air pollutants in six coal samples from the Pittsburgh coal bed from Ohio, Pennsylvania, and West Virginia. In this sample suite arsenic and beryllium have larger ranges than they do in tables 1 or 2. Finally, at bench scale, the smallest sampling scale in the data base, table 4 shows large trace element ranges, among bench samples from the Pittsburgh coal bed, for arsenic, beryllium, cobalt, chromium, and mercury. These data demonstrate that trace element ranges may be larger within a coal bed than between coal basins (for example see mercury).

STATISTICAL CORRELATIONS

One indirect method of deducing an element's mode of occurrence is to determine its correlation with ash yield, sulfur, or other coal quality parameters. This is often a useful, but potentially misleading, procedure. In a geologic data base, such as the USGS Coal Quality Data Base, correlation coefficients generally reflect a common source rather than a close chemical or physical affinity. For example, Cecil and others (6) found evidence of extensive mobilization of many trace elements in the Upper Freeport coal bed. Because this geochemical system was closed for many elements, the elements retained statistical correlations with ash yield and other parameters, despite these elements having changed chemical form and distribution patterns. Finkelman (7) came to a similar conclusion on the basis of research on the Gulf Coast lignites.

MODES OF OCCURRENCE AND TEXTURAL RELATIONS

The USGS Coal Quality Data Base provides information on the concentration and vertical and lateral distribution of many coal quality parameters including the major, minor, and trace elements. This information is useful, especially for seeking coals with particular coal quality characteristics or for determining regional trends. However, to anticipate the environmental impact, technological behavior, or byproduct potential of an element, information is needed on the modes of occurrence (chemical form) and textural relations of the element. Currently, this information is not included in the data base. The USGS has, however, conducted extensive investigations on the modes of occurrence and textural relations of the elements in coal (8-12).

CONCLUSION

The trace element information contained in the U.S. Geological Survey Coal Quality Data Base may aid EPA in addressing several provisions of the 1990 Clean Air Act Amendments. Information on the modes of occurrence and textural relations of potentially hazardous elements may lead to more efficient mitigation of the environmental impact of these elements found in coal.

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Table 1. Variation of potential air toxics among coal basins. (Values are arithmetic means in parts-per-million on a whole-coal basis; figures in parantheses are number of samples.)

Element	Appalachian basin (4,700)	Interior Province (800)	Gulf Coast lignites (200)	Fort Union lignites (350)	Powder River basin (800)
Antimony	1.4	1.5	1.0	0.69	0.57
Arsenic	35.0	20.0	10.0	11.0	5.6
Beryllium	2.5	2.4	2.4	1.0	0.84
Cadmium	0.1	4.2	0.55	0.16	0.16
Chromium	17.0	19.0	24.0	6.4	8.5
Cobalt	7.2	10.0	7.2	2.4	2.3
Lead	8.4	40.0	21.0	4.8	5.5
Manganese	29.0	78.0	150.0	83.0	63.0
Mercury	0.21	0.15	0.22	0.14	0.12
Nickel	17.0	27.0	13.0	4.1	6.4
Selenium	3.5	3.2	5.7	0.82	1.1
Uranium	1.7	3.1	23.0	1.8	1.6

Table 2. Variation of potential air toxics among coal beds in the Appalachian basin. (Values are arithmetic means in parts-per-million on a whole-coal basis; figures in parentheses are number of samples.)

Element	Meigs Creek coal bed (54)	Redstone coal bed (80)	Pittsburgh coal bed (194)	Lower Freeport coal bed (119)	Lower Kittanning coal bed (219)	Sewell coal bed (73)
Antimony	0.3	0.7	0.6	1.2	0.9	1.1
Arsenic	6.7	29.1	20.4	37.3	25.2	11.1
Beryllium	1.4	1.6	1.4	2.7	2.6	2.2
Cadmium	0.08	0.07	0.11	0.11	0.14	0.10
Chromium	16.4	13.8	14.7	17.4	16.8	11.8
Cobalt	3.2	3.5	4.6	7.6	6.7	8.0
Lead	5.3	4.0	4.9	10.4	10.6	5.5
Manganese	30.8	46.3	31.9	42.8	27.2	18.5
Mercury	0.12	0.22	0.18	0.34	0.24	0.16
Nickel	9.5	9.5	10.7	20.4	20.5	18.9
Selenium	2.9	2.4	1.9	5.0	4.3	2.4
Uranium	1.8	1.7	1.1	1.7	1.8	1.4

Table 3. Lateral distribution of potential air toxics within the Pittsburgh coal bed from Ohio, Pennsylvania, and West Virginia. (Values are arithmetic means in parts-per-million on a whole-coal basis.)

	Sample					
Element	1	2	3	4	5	6
Antimony	0.4	1.4	0.4	0.4	1.4	0.3
Arsenic	13.3	75.1	15.0	9.6	79.8	10.0
Beryllium	1.1	1.2	1.6	1.4	1.0	0.3
Cadmium	0.10	0.07	0.14	0.06	0.09	0.04
Chromium	14.4	9.3	10.1	10.3	9.2	10.2
Cobalt	2.8	3.1	11.8	2.7	4.9	1.7
Lead	3.6	3.7	1.5	3.8	6.9	1.0
Manganese	17.8	19.1	55.1	19.7	25.6	25.3
Mercury	0.10	0.22	0.60	0.16	0.28	0.22
Nickel	7.1	6.3	20.9	9.0	9.5	4.3
Selenium	1.5	3.4	3.0	0.9	1.7	1.0
Uranium	0.8	0.3	2.0	0.9	1.4	2.4

Table 4. Variations of potential air toxics from the top to the bottom of a set of bench samples from the Pittsburgh coal bed in Ohio. (Values are in parts-per-million on a whole coal basis. Total thickness of the bed is 52.5 inches.)

	Sample						
	top 1	2	3	4	5	6	bottom 7
Element							
Antimony	0.6	0.2	0.2	0.2	0.3	0.3	0.4
Arsenic	10.4	12.6	4.9	6.3	8.2	31.9	12.8
Beryllium	3.0	1.5	0.8	0.7	1.6	1.3	3.4
Cadmium	0.10	0.09	0.03	0.05	0.08	0.08	0.09
Chromium	30.4	7.4	6.9	9.8	32.7	11.8	12.5
Cobalt	9.2	2.2	1.6	2.1	6.6	1.3	3.3
Lead	8.7	1.6	1.3	1.4	5.5	1.5	5.1
Manganese	12.6	10.3	8.8	7.34	24.8	8.4	13.7
Mercury	0.24	0.29	0.10	0.14	0.20	0.19	0.05
Nickel	16.6	5.8	2.9	4.7	21.3	5.9	13.7
Selenium	8.5	3.3	1.1	1.5	2.2	0.9	0.9
Uranium	2.0	0.3	0.3	0.4	1.3	0.3	0.6