Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference maybe from a previous version of the section and no longer cited. The primary source should always be checked.

AP42 Section:	1.1
Reference:	43
Title:	Draft Final Report. A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing an ESP/Wet FGD System. Volumes One, Two, and Three. Battelle, Columbus, Ohio. December 1993.

Coal Rpt 26

DRAFT FINAL REPORT

VOLUME 1 of 3 - SAMPLING

A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing an ESP/Wet FGD System

Contract DE-AC22-93PC93251

To

U.S. Department of Energy

Pittsburgh Energy Technology Center

December 1993

Battelle

. . . Putting Technology To Work

2.0 SITE DESCRIPTION

The host site for this study was the Coal Creek Station Unit No. 1, operated by Cooperative Power. This section describes the plant, including key individual components such as the ESP and the wet FGD unit (scrubber). Following descriptions of the plant, the flue gas and solid/liquid process streams at which samples were collected are described. This section concludes with presentation of the expected and actual operating conditions of the plant.

2.1 Plant Description

2.1.1 General

The Coal Creek Station is located about 50 miles north of Bismarck, North Dakota, near Underwood, North Dakota. Coal Creek Station is a two-unit, zero discharge, 1,100-megawatt, mine-mouth plant located in a lignite field. The two units are identical. The study described in this report was conducted on Unit No. 1. Each unit has a tangentially fired, water walled, dry bottom furnace, with a Combustion Engineering Controlled Circulation boiler. The furnace is fueled by lignite that is conveyed into the plant from the Falkirk mine located adjacent to the plant. Coal is fed to the boiler through eight pulverizers, of which seven are in operation at any one time. Each unit is equipped with an electrostatic precipitator (ESP) for particulate removal, and with a wet flue gas desulfurization unit (FGD, denoted as scrubber) for sulfur dioxide (SO_2) removal. Each of these components is described below.

A schematic of the Coal Creek Unit 1 process flow is shown in Figure 2-1. The sampling locations for this study are numbered in Figure 2-1, and are listed in Table 2-1, which shows the sample location numbering scheme developed for this study. Figure 2-1 and Table 2-1 distinguish three types of sampling locations: flue gas/particulate sampling locations, designated G; solid sampling locations, designated S; and liquid sampling locations, designated L.

ESP is rated at a removal efficiency of 99.5 percent at inlet particulate loadings of greater than 1.16 grains per actual cubic foot (2.65 grams per actual cubic meter). At lower inlet loadings, the outlet particulate loading is rated to be no higher than 0.0058 grains per actual cubic foot (0.013 grams per actual cubic meter).

Ash from the 48 hoppers is removed by a pressurized pneumatic system that dumps two hoppers at a time. In normal operation at full load, the dumping of ESP hoppers takes about one hour in total, with successively shorter dump times required for successive hopper rows (i.e., 25 minutes for row 1, 15 minutes for row 2, etc.). During the present study, hopper rows 3 through 6 were put on hold from the dumping cycle, to allow accumulation of more ash so that samples could be collected. This action consequently shortened the dumping cycle of the first two rows, due to more frequent cycling of dumping. However, the shortened dumping cycle of rows 1 and 2 did not impair the collection of sample from those rows. Flue gas leaves the ESP in four ducts which connect to four induced draft fans. The gas flow from these fans recombines into two ducts that connect to the Unit 1 scrubber system.

2.1.4 Scrubber (Wet FGD System)

The Coal Creek Unit 1 scrubber is a Combustion Engineering Air Quality Control System (AQCS), which removes SO_2 from the flue gas by means of four countercurrent spray towers using an alkali slurry. The system is designed to remove 90 percent of the SO_2 from up to 60 percent of the flue gas flow. The unscrubbed flue gas is recombined with the scrubbed gas to reheat it. Flexibility in responding to variations in fuel sulfur content is provided by the variable gas bypass flow, and by the capability of operating with fewer than four spray towers at a time.

Each spray tower has three levels of spray nozzles oriented countercurrent (i.e., downward) to the flue gas flow. A slurry liquid to flue gas ratio of 60 gallons per minute per 1000 actual cubic feet per minute is maintained to achieve the 90 percent removal efficiency. Slurry droplets are removed from the gas stream by a bulk entrainment separator and two levels of mist eliminators. The flue gas leaving the top of the scrubber towers contains essentially no entrained droplets, but is saturated with water vapor at the exit temperature of about 135 F. Mixing of 40 percent unscrubbed flue gas at the inlet temperature of about 320 F with 60 percent scrubbed flue gas at 135 F results in a stack gas temperature of about 210 F. At an inlet SO_2 level of 1000 ppm, an efficiency of 90 percent on 60 percent of the flue gas produces a stack SO_2 level of 460 ppm.

Figure 2-1 shows the flow schematic of the scrubber. Alkaline slurry is pumped to the spray towers from two slurry reaction tanks, and drains back after collection at the bottom of the scrubber. The scrubber slurry is maintained at a pH of about 7 by intermittent automatic introduction of lime slurry into the reaction tanks. The lime slurry is made up as needed from commercial pebble lime and scrubber makeup water, to a nominal solids content of 15 percent. This slurry is added to the reaction tanks, along with scrubber makeup water for tank level control. Scrubber makeup water also enters the system as an intermittent flow of mist eliminator wash water (not shown in Figure 2-1).

Table 2-2 shows information on the composition of the scrubber slurry in the Unit 1 scrubber. Most of these analyses were done after the field measurements reported here, but are considered representative of the scrubber slurry composition for the study period.

The plant circulating water used throughout the Coal Creek plant is treated with several additives. Listed below are the additives and the annual quantities used; these values apply to the entire plant circulating water system, not to Unit 1 or the scrubber specifically.

Sulfuric acid (H_2SO_4) - 2,000 tons per year
Polymaleic acid - 6,600 pounds per year
Polyacrylate - 36,500 pounds per year
Chlorine - 125 tons per year
Chlorine dioxide (ClO_2) - 65 tons per year
Zinc chloride ($ZnCl_2$) - 75,000 pounds per year

The scrubber bypass flow can be adjusted by means of dampers in the flow line. The bypass flow results from the convergence (from opposite directions) of the two combined flow streams downstream of the four induced draft fans at the outlet of the ESP. At the convergence point, the combined bypass flows turn vertically to meet the scrubbed flue gas but were relatively constant for any single field. The data in Tables 2-6 through 2-15 have been reviewed for trends, but no consistent trends have been found that appear to explain (e.g.) the decreasing flue gas particulate loading at Location 5a (Table 2-3).

Table 2-16 shows results from analysis of daily composite run-of-mine lignite samples from each day of the study. Several different characteristics of the coal are shown, on both a dry and wet (i.e., as-received) basis.. Some variation in coal composition was noted during the study. For example, ash content was higher, and sulfur content and heating value lower, on June 24 than on other days. The variation in sulfur content, alluded to in Section 2.1.4 in the context of scrubber operations, is clearly evident in Table 2-16. However, the lignite composition was within expected ranges for all characteristics.

No problems of any kind were encountered in operation of the plant at any time during the field study. Operating conditions remained stable near the nominal values at all times. No deviations from the sampling plan resulted from operation of the plant during sampling. One small deviation from the plan was the finding before sampling began that the condenser water sampling locations, originally designated in the sampling plan as Locations 11 and 12, were redundant with the make-up water, Location 9 (Figure 2-1). As a result, the condenser water locations were omitted from sampling, and designation 11 was assigned to the scrubber make-up water (Figure 2-1). Location 12 was dropped from the sampling location list (see Table 2-1).

2.3.3 Process Trends Graphs

Figures 2-3 through 2-38 are plots of key operating conditions shown in Table 2-5 against time for each test day. When plant staff recorded data for periods longer than the actual sampling period (e.g., generally data were recorded from 7:00 am while sampling began about 9:00 or 10:00 am), all of the data are shown on the plots. Figures 2-3 through 2-38 are arranged in the same order as Table 2-5, e.g., Figures 2-3 through 2-8 show lignite feed rates. As can be seen from Figures 2-3 through 2-38 and the low values for the standard deviations for operating conditions reported in Table 2-5, Coal Creek No. 1 was operated at nearly constant conditions for the period of the study.

TABLE 2-16. RUN-OF-MINE LIGNITE CHARACTERISTICS ON SAMPLING DAYS, COAL CREEK UNIT 1[a]

Date	Moisture		Ash		Heat Content			Sulfur		
	Percent Moisture (Total)	Percent Moisture (Air Dried)	Percent Ash (As received)	Percent Ash (Dry Basis)	Btu/lb (As received)	Btu/lb (Dry Basis)	Btu/lb (Moisture and Ash Free)	Percent Sulfur (As Received)	Percent Sulfur (Dry Basis)	Percent Soluble Sodium in Ash
June 21, 1993	36.82	31.35	11.28	17.85	6378	10095	12287	0.78	1.23	0.70
June 22, 1993	38.14	32.61	8.93	14.44	6356	10275	12009	0.60	0.96	0.73
June 23, 1993	38.42	33.50	10.09	16.38	6217	10095	12073	0.58	0.94	0.95
June 24, 1993	38.30	33.39	11.78	19.10	5977	9688	11975	0.57	0.92	1.09
June 26, 1993	38.88	35.20	10.51	17.19	6180	10110	12209	0.86	1.40	0.67
June 27, 1993	39.29	35.32	9.94	16.38	6274	10334	12358	0.95	1.57	0.65

(a) Results provided by Coal Creek.

TABLE 3-6. NUMBER OF SAMPLING RUNS AT COAL CREEK FLUE GAS SAMPLING LOCATIONS

Run Type	Location 4a	4b	5a	5b	6a	6b
Organic						
Modified Method 5 (SVOC)	3		3		3	3
Canisters[b] (VOC)	9		6		9	10[f]
VOST[b] (VOC)	9		9		12[c]	9
TO-5 (Aldehydes)	3		3		3	3
Inorganic						
Multi-Metals Train	3		3		3	3
HEST Sampler	4[d]		3	3	3	3
Method 26A (Anions)	3		3		3	3
APHA 401 (Ammonia)	3		3		2	3
APHA 808 (Cyanide)	3		2		3	3
Method 26A Filter (Carbon)	3		2		3	
Method 26A Filter (Radionuclides)	3		2		3	
Method 5 (Particle Mass)		3		3[e]		
Impactors (Particle Size Distribution)					3	3
Cyclones (Particle Size Distribution)	3	3	3	3		

(a) All samples collected using Plume Simulating Dilution Sampler (PSDS).
(b) Each canister run used three canisters; each VOST run used three sets of VOST cartridges.
(c) Includes VOST audit run on June 23, 1993.
(d) Includes special HEST QA run on June 25, 1993.
(e) Also analyzed for elements.
(f) Only nine analyzed.

TABLE 6-30. EMISSION FACTORS FOR ELEMENTS (lb/10^12 BTU)

Analyte	C-6a-MUM-622	C-6a-MUM-624	C-6a-MUM-627	AVERAGE	TU
Aluminum	634	593	506	578	169
Antimony	0.225	0.155	0.172	0.18	0.09
Arsenic	1.47	1.21	1.02	1.2	0.58
Barium	189	154	143	162	61
Beryllium	ND 0.880	ND 0.833	ND 0.826	0.85 #	0.10
Boron	7.65	42.0	8.59	19	49
Cadmium	ND 1.66	ND 1.58	ND 1.56	1.6 #	0.19
Calcium	1541	1181	1201	1308	513
Chromium	162 *	3.86	15.6	10 **	218
Cobalt	2.92	ND 0.833	ND 0.826	1.5 #	3.0
Copper	11.8	2.08	ND 0.992	4.9 #	15
Lead	0.784	0.648	0.634	0.69	0.21
Manganese	41.1	20.2	28.2	30	26
Mercury	8.27	12.9	7.27	9.5	7.5
Molybdenum	7.15 *	0.507	0.520	0.51 **	9.5
Nickel	151 *	2.38	7.89	5.1 **	209
Potassium	103	124	100	109	34
Selenium	11.3	8.31	5.33	8.3	7.4
Sodium	226	222	206	218	32
Titanium	48.8	40.3	36.3	42	16
Vanadium	5.40	4.15	3.56	4.4	2.4

TU = Total uncertainty.
ND = Emission factor calculated using one half of the detection limit.
# Average emission factor calculated from one or more non-detect values.
* These values are believed to result from contamination by stainless steel.
** Average of two values from 6/24 and 6/27.

TABLE 6-32. EMISSION FACTORS FOR AMMONIA/CYANIDE (lb/10^12 BTU)

Analyte	C-6a-NH4-622 C-6a-CN-622		C-6a-NH4-624 C-6a-CN-624		C-6a-NH4-627 C-6a-CN-627		AVERAGE	TU
Ammonia	ND	1.87	ND	1.82	ND	1.92	1.9 #	0.18
Cyanide		41.4		36.4		74.0	51	51

TU = Total uncertainty.
ND = Emission factor calculated using one half of the detection limit.
# Average emission factor calculated from one or more non-detect values.

TABLE 6-34. EMISSION FACTORS FOR ANIONS (lb/10^12 BTU)

Analyte	C-6a-FCL-622	C-6a-FCL-624	C-6a-FCL-627	AVERAGE	TU
Hydrogen Chloride	1459	1294	1263	1339	285
Hydrogen Fluoride	5406	3975	2547	3976	3561
Chloride (Particulate) *	6.52	ND 0.359	3.52	3.5 #	7.6
Fluoride (Particulate) *	127	175	137	146	64
Sulfate (Particulate) *	859	1960	836	1218	1596
Phosphate (Particulate) *	15.9	ND 0.721	6.87	7.8 #	19

TU = Total uncertainty.
ND = Emission factor calculated using one half of the detection limit.
# Average emission factor calculated from one or more non-detect values.
* Sampling for anions was conducted at a single point in the duct; traverses were not made.

TABLE 6-36. EMISSION FACTORS FOR VOC (lb/10^12 BTU)

Analyte		C-6a-VOS-621		C-6a-VOS-623		C-6a-VOS-626	AVERAGE	TU
Chloromethane		109		75.6		133	106	72
Bromomethane	ND	3.51		2.93		6.47	4.3 #	4.7
Vinyl Chloride	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Chloroethane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Methylene Chloride		NC		NC		NC	NC	NC
Acetone		NC		NC		NC	NC	NC
Carbon Disulfide	ND	3.51		3.83	ND	2.99	3.4 #	1.1
1,1-Dichloroethene	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
1,1-Dichloroethane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
trans-1,2-Dichloroethene	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Chloroform	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
1,2-Dichloroethane		3.52	ND	3.18	ND	2.99	3.2 #	0.74
2-Butanone		6.28		14.4		8.60	9.8	10
1,1,1-Trichloroethane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Carbon Tetrachloride	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Vinyl Acetate	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Bromodichloromethane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
1,2-Dichloropropane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
cis-1,3-Dichloropropylene	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Trichloroethene	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Dibromochloromethane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
1,1,2-Trichloroethane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Benzene		50.0		48.9		23.0	41	38
trans-1,3-Dichloropropylene	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
2-Chloroethylvinylether	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Bromoform	ND	3.51		2.96	ND	2.99	3.1 #	0.82
4-Methyl-2-Pentanone	ND	3.51		11.4	ND	2.99	6.0 #	12
2-Hexanone		6.36		24.7		3.79	12	28
Tetrachloroethene	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
1,1,2,2-Tetrachloroethane	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Toluene		31.9		24.8		14.8	24	21
Chlorobenzene		3.58	ND	3.18	ND	2.99	3.3 #	0.81
Ethylbenzene	ND	3.51	ND	3.18	ND	2.99	3.2 #	0.72
Styrene		3.64	ND	3.18	ND	2.99	3.3 #	0.89
Xylenes (Total)		3.70		3.92	ND	2.99	3.5 #	1.3

TU = Total uncertainty.
ND = Emission factor calculated using one half of the detection limit.
NC = Not calculated.
# Average emission factor calculated from one or more non-detect values.

TABLE 6-38. EMISSION FACTORS FOR PAH/SVOC (lb/10^12 BTU)

Analyte	C-6a-MM5-F+X-621		C-6a-MM5-F+X-623		C-6a-MM5-F+X-626		AVERAGE		TU
Benzylchloride	ND	0.0009	ND	0.0008		0.0154	0.0057	#	0.0208
Acetophenone		0.3839		0.3922		0.8513	0.5425		0.6650
Hexachloroethane	ND	0.0009	ND	0.0008	ND	0.0008	0.0009	#	0.0001
Naphthalene		0.1717		0.2639		0.3291	0.2549		0.1973
Hexachlorobutadiene	ND	0.0009	ND	0.0008	ND	0.0008	0.0009	#	0.0001
Quinoline	ND	0.0089	ND	0.0084	ND	0.0083	0.0085	#	0.0011
2-Chloroacetophenone		0.1276		0.1002		0.1489	0.1256		0.0616
2-Methylnaphthalene		0.0499		0.0364		0.0364	0.0409		0.0196
1-Methylnaphthalene		0.0190		0.0130		0.0133	0.0151		0.0084
Hexachlorocyclopentadiene	ND	0.0009	ND	0.0008	ND	0.0008	0.0009	#	0.0001
Biphenyl		0.0275		0.0219		0.0197	0.0230		0.0101
Acenaphthylene		0.0096		0.0030		0.0188	0.0105		0.0197
2,6-Dinitrotoluene	ND	0.0009	ND	0.0008	ND	0.0008	0.0009	#	0.0001
Acenaphthene		0.0270		0.0074		0.0175	0.0173		0.0243
Dibenzofuran		0.0673		0.0450		0.0425	0.0516		0.0342
2,4-Dinitrotoluene		0.0123		0.0064	ND	0.0008	0.0065	#	0.0143
Fluorene		0.0618		0.0335		0.0293	0.0415		0.0440
Hexachlorobenzene	ND	0.0009	ND	0.0008	ND	0.0008	0.0009	#	0.0001
Pentachlorophenol	ND	0.0009	ND	0.0008	ND	0.0008	0.0009	#	0.0001
Phenanthrene		0.5247		0.3313		0.0866	0.3142		0.5452
Anthracene		0.0184		0.0133		0.0123	0.0147		0.0081
Fluoranthene		0.0588		0.0332		0.0348	0.0422		0.0357
Pyrene		0.0216		0.0118		0.0152	0.0162		0.0124
Benz(a)anthracene		0.0029		0.0019		0.0014	0.0021		0.0019
Chrysene		0.0079		0.0048		0.0033	0.0053		0.0058
Benzo(b & k)fluoranthene		0.0069		0.0026		0.0040	0.0045		0.0055
Benzo(e)pyrene		0.0010		0.0007		0.0014	0.0011		0.0009
Benzo(a)pyrene		0.0011	ND	0.0002		0.0014	0.0009	#	0.0015
Indeno(1,2,3-c,d)pyrene		0.0007	ND	0.0002		0.0011	0.0006	#	0.0011
Dibenzo(a,h)anthracene		0.0007		0.0006		0.0009	0.0007		0.0005
Benzo(g,h,i)perylene		0.0007	ND	0.0002		0.0008	0.0006	#	0.0009

TU = Total uncertainty
ND = Emission factor calculated using one half of the detection limit.
# Average emission factor calculated from one or more non-detect values.

TABLE 6-40. EMISSION FACTORS FOR DIOXINS/FURANS (lb/10^12 BTU)

Analyte	C-6a-MM5-621	C-6a-MM5-623	C-6a-MM5-626	AVERAGE	TU
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND 9.40E-07	ND 9.00E-07	ND 1.12E-06	9.90E-07 #	3.00E-07
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ND 9.00E-07	ND 1.63E-06	ND 1.09E-06	1.21E-06 #	9.40E-07
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ND 1.20E-06	ND 1.23E-06	ND 7.10E-07	1.05E-06 #	7.30E-07
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ND 1.30E-06	ND 1.69E-06	ND 1.73E-06	1.57E-06 #	6.00E-07
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ND 1.90E-06	ND 1.83E-06	ND 1.16E-06	1.63E-06 #	1.02E-06
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1.44E-06	4.53E-06	3.72E-06	3.23E-06	3.98E-06
Octachlorodibenzo-p-dioxin	8.11E-06	2.17E-05	1.56E-05	1.51E-05	1.69E-05
2,3,7,8-Tetrachlorodibenzofuran	1.23E-05	9.38E-06	7.94E-06	9.89E-06	5.63E-06
1,2,3,7,8-Pentachlorodibenzofuran	ND 2.72E-06	ND 1.69E-06	ND 2.10E-06	2.17E-06 #	1.31E-06
2,3,4,7,8-Pentachlorodibenzofuran	ND 1.83E-06	ND 2.16E-06	ND 1.52E-06	1.84E-06 #	8.20E-07
1,2,3,4,7,8-Hexachlorodibenzofuran	ND 2.09E-06	ND 2.08E-06	ND 1.61E-06	1.93E-06 #	7.00E-07
1,2,3,6,7,8-Hexachlorodibenzofuran	ND 1.56E-06	ND 1.72E-06	ND 1.31E-06	1.53E-06 #	5.30E-07
1,2,3,7,8,9-Hexachlorodibenzofuran	ND 3.23E-06	ND 2.49E-06	ND 2.17E-06	2.63E-06 #	1.36E-06
2,3,4,6,7,8-Hexachlorodibenzofuran	ND 9.00E-07	ND 1.08E-06	ND 8.20E-07	9.30E-07 #	3.40E-07
1,2,3,4,6,7,8-Heptachlorodibenzofuran	ND 2.09E-05	ND 8.56E-06	ND 5.43E-06	1.16E-05 #	2.03E-05
1,2,3,4,7,8,9-Heptachlorodibenzofuran	ND 1.59E-06	ND 2.05E-06	ND 2.08E-06	1.91E-06 #	7.00E-07
Octachlorodibenzofuran	6.33E-06	ND 7.16E-06	5.40E-06	6.29E-06 #	2.25E-06

TU = Total uncertainty
ND = Emission factor calculated using one half of the detection limit.
# Average emission factor calculated from one or more non-detect values.

2,3,7,8-
Tetra
Penta
Hex
Hep
Oct
Total CDD
2378 Equiv

TABLE 6-42. EMISSION FACTORS FOR ALDEHYDES (lb/10^12 BTU)

Analyte	C-6a-ALD-621	C-6a-ALD-623	C-6a-ALD-626	AVERAGE	TU
Formaldehyde	3.27	ND 1.10	ND 1.09	1.8 #	3.1
Acetaldehyde	75.3	54.6	72.1	67	28
Acrolein	ND 1.13	ND 1.10	ND 1.09	1.1 #	0.10
Propionaldehyde	17.8	9.08	9.36	12	12

TU = Total uncertainty.
ND = Emission factor calculated using one half of the detection limit.
# Average emission factor calculated from one or more non-detect values.

TABLE 6-46. EMISSION FACTORS FOR PARTICULATE MATTER (lb/10^12 BTU)

Analyte	C-6a-MUM-622	C-6a-MUM-624	C-6a-MUM-627	AVERAGE	TU
Particulate Matter	24722	4820	1557	10367	31112

TU = Total uncertainty

TEST REPORT TITLE:	A Study of Toxic Emissions From a Coal-Fired Power Plant Utilizing an ESP/Wet FGD System. Battelle, Columbus, Ohio. December 29, 1993.
COAL EF DATABASE REFERENCE NO.	26
FILENAME	DOE6.WK1
FACILITY:	Underwood, North Dakota

PROCESS DATA

Coal type a	Lignite
Boiler configuration a	Pulverized, Dry bottom, tangential
Coal source a	North Dakota
SCC	10100302
Control device 1 a	ESP
Control device 2 b	Flue Gas Desulfurization- Wet Limestone Scrubber (FGD-WLS)
Control device 3	None
Data Quality	B
Process Parameters c	550 MW
Test methods d	Assumed EPA, or EPA-approved, test methods
Number of test runs e	2,3
Coal HHV, as received (Btu/lb) f	6,230
Coal HHV, as received (Btu/ton)	12,460,000
Coal HHV, as received (MMBtu/ton)	12.5

a Page 2-1

b Pages 2-1, 2-4, and 2-5.

c Page 2-1. 2 idential units @ 1,100 MW- one unit = 550 MW.

d Page 3-26.

e See pages referenced below by groups of EFs.

f Page 2-33, average of "As received" values.

METALS EMISSION FACTORS

Pollutant	Emission Factor (lb/10^12 Btu) a	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
Aluminum	578	5.78E-04	7.20E-03
Antimony	0.18	1.80E-07	2.24E-06
Arsenic	1.2	1.20E-06	1.50E-05
Barium	162	1.62E-04	2.02E-03
Beryllium d	0.85	8.50E-07	1.06E-05
Boron	19	1.90E-05	2.37E-04
Cadmium d	1.6	1.60E-06	1.99E-05
Calcium	1308	1.31E-03	1.63E-02

Chromium e	10.0	1.00E-05	1.25E-04
Cobalt c	1.5	1.50E-06	1.87E-05
Copper b	4.9	4.90E-06	6.11E-05
Lead	0.69	6.90E-07	8.60E-06
Manganese	30	3.00E-05	3.74E-04
Mercury	9.5	9.50E-06	1.18E-04
Molybdenum e	0.51	5.10E-07	6.35E-06
Nickel e	5.1	5.10E-06	6.35E-05
Potassium	109	1.09E-04	1.36E-03
Selenium	8.3	8.30E-06	1.03E-04
Sodium	218	2.18E-04	2.72E-03
Titanium	42	4.20E-05	5.23E-04
Vanadium	4.4	4.40E-06	5.48E-05

a Page 6-76, "Average" values.
b Detection limit value (1/2) for one run used in developing EF.
c Detection limit values (1/2) for two runs used in developing EF.
d Pollutant was not detected in any of the sampling runs.
e Data from one run not used, EF based on data from two runs.

AMMONIA/CYANIDE EMISSION FACTORS

Pollutant	Emission Factor (lb/10^12 Btu) a	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
Ammonia d	1.9	1.90E-06	2.37E-05
Cyanide	51	5.10E-05	6.35E-04

a Page 6-78
d Pollutant was not detected in any sampling runs

HCl, HFl EMISSION FACTORS

Pollutant	Emission Factor (lb/10^12 Btu) a	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
Hydrogen Chloride	1,339	1.34E-03	1.67E-02
Hydrogen Fluoride	3,976	3.98E-03	4.95E-02

a Page 6-80

VOC EMISSION FACTORS

Pollutant	Emission Factor (lb/10^12 Btu) a	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
Chloromethane (Methyl Chloride)	106	1.06E-04	1.32E-03

Bromomethane (Methyl Bromide) b	4.3	4.30E-06	5.36E-05
Vinyl Chloride d	3.2	3.20E-06	3.99E-05
Chloroethane (Ethyl Chloride) d	3.2	3.20E-06	3.99E-05
Carbon Disulfide c	3.4	3.40E-06	4.24E-05
1,1-Dichloroethane (Ethylidene Dichloride) d	3.2	3.20E-06	3.99E-05
Chloroform d	3.2	3.20E-06	3.99E-05
1,2-Dichloroethane (Ethylene Dichloride) c	3.2	3.20E-06	3.99E-05
2-Butanone (Methyl Ethyl Ketone)	9.8	9.80E-06	1.22E-04
1,1,1-Trichloroethane d	3.2	3.20E-06	3.99E-05
Carbon Tetrachloride d	3.2	3.20E-06	3.99E-05
Vinyl Acetate d	3.2	3.20E-06	3.99E-05
1,2-Dichloropropane (Propylene Dichloride) d	3.2	3.20E-06	3.99E-05
Trichloroethene d	3.2	3.20E-06	3.99E-05
1,1,2-Trichloroethane d	3.2	3.20E-06	3.99E-05
Benzene	41	4.10E-05	5.11E-04
1,3-Dichloropropylene d	3.2	3.20E-06	3.99E-05
Bromoform c	3.1	3.10E-06	3.86E-05
Tetrachloroethene d	3.2	3.20E-06	3.99E-05
1,1,2,2-Tetrachloroethane d	3.2	3.20E-06	3.99E-05
Toluene	24	2.40E-05	2.99E-04
Chlorobenzene c	3.3	3.30E-06	4.11E-05
Ethylbenzene d	3.2	3.20E-06	3.99E-05
Styrene c	3.3	3.30E-06	4.11E-05
Xylenes b	3.5	3.50E-06	4.36E-05

a Page 6-82 (only 189 HAPs).

b Detection limit values (1/2) for one run used in developing EF.

c Detection limit values (1/2) for two runs used in developing EF.

d Pollutant not detected in any sampling runs.

PAH/SVOC EMISSION FACTORS

Pollutant	Emission Factor (lb/10^12 Btu) a	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
Naphthalene	0.2549	2.55E-07	3.18E-06
Acenaphthene	0.0173	1.73E-08	2.16E-07
Dibenzofurans	0.0516	5.16E-08	6.43E-07
2,4-Dinitrotoluene b	0.0065	6.50E-09	8.10E-08
Fluorene	0.0415	4.15E-08	5.17E-07
Hexachlorobenzene d	0.0009	9.00E-10	1.12E-08
Phenanthrene	0.3142	3.14E-07	3.91E-06
Anthracene	0.0147	1.47E-08	1.83E-07
Fluoranthene	0.0422	4.22E-08	5.26E-07
Pyrene	0.0162	1.62E-08	2.02E-07
Benz(a)anthracene b	0.0021	2.10E-09	2.62E-08
Chrysene	0.0053	5.30E-09	6.60E-08
Benzo(b,k)fluoranthene	0.0045	4.50E-09	5.61E-08
Benzo(a)pyrene b	0.0009	9.00E-10	1.12E-08

Indeno(1,2,3-c,d)pyrene b	0.0006	6.00E-10	7.48E-09
Benzo(g,h,i)perylene b	0.0006	6.00E-10	7.48E-09

a Page 6-84 (most common PAHs, 189 HAPs).

b Detection limit values (1/2) for one run used in developing EF.

c Detection limit values (1/2) for two runs used in developing EF.

d Pollutant not detected in any sampling runs.

DIOXINS/FURANS EMISSION FACTORS

Pollutant	Emission Factor (lb/10^12 Btu) a	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
2,3,7,8-TCDD d	9.90E-07	9.90E-13	1.23E-11
OCDD	1.51E-05	1.51E-11	1.88E-10
2,3,7,8-TCDF	9.89E-06	9.89E-12	1.23E-10
OCDF b	6.29E-06	6.29E-12	7.84E-11

a Page 6-86

b Detection limit values (1/2) for one run used in developing EF.

d Pollutant not detected in any sampling runs.

ALDEHYDES EMISSION FACTORS

Pollutant	Emission Factor (lb/10^12 Btu) a	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
Formaldehyde c	1.8	1.80E-06	2.24E-05
Acetaldehyde	67	6.70E-05	8.35E-04
Acrolein d	1.1	1.10E-06	1.37E-05
Propionaldehyde	12	1.20E-05	1.50E-04

a Page 6-88

b Detection limit values (1/2) for one run used in developing EF.

c Detection limit values (1/2) for two runs used in developing EF.

d Pollutant not detected in any sampling runs.

PM, FILTERABLE, EMISSION FACTOR a

Emission Factor (lb/10^12 Btu) b	Emission Factor (lb/MMBtu)	Emission Factor (lb/ton)
10,367	1.04E-02	1.29E-01

a Charlie Parrish, Radian, says PM reported from a Multi-metals Method 29 train is "filterable".

b Page 6-92