PAPER 1[1]

ATMOSPHERIC DISPERSION MODELING OF PRIMARY POLLUTANTS FROM ELECTRIC POWER PLANTS: APPLICATION TO A COAL-FIRED POWER PLANT

1. INTRODUCTION

The normal operation of a power plant generally releases pollutants to the atmosphere. The objective of this paper is to describe a modeling method to estimate the changes in air pollutant concentrations that result from these emissions. This modeling approach is applicable to coal, biomass, oil, and natural gas technologies. As an example, this paper uses a hypothetical 500 megawatt (MW) coal-fired power plant, located at a Southeast Reference site in the U.S. and at a Southwest Reference Site. The numerical results in this paper are used in the ORNL/RFF (1994) report on coal fuel cycle externalities.

The pollutants resulting from the operation of the power plant may be classified as primary (emitted directly from the plant) or secondary (formed in the atmosphere from primary pollutants). The primary pollutants of interest in this paper are nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter and metals.

2. METHODOLOGY

The ground-level pollutant concentrations that could be expected to occur as the result of the operation of a 500 MW coal-fired power plant are predicted using atmospheric dispersion modeling. An atmospheric dispersion model is a set of mathematical equations used to characterize the dilution of pollutants by the wind. Some models also account for the chemical transformation of pollutants over time.

[1]Based largely on a working paper by C. M. McIlvaine.

Using stack information (i.e., stack diameter, exit gas velocity, and exit gas temperature), the model predicts the release height of pollutants to the atmosphere. Wind direction, wind speed and other meteorological measurements made in the vicinity of the stack are used to predict the dimensions (i.e., vertical and horizontal spread) of the plume and its travel path downwind. The model calculates pollutant concentrations at receptor locations which are defined by a system of grid points.

Procedures employed in the computer modeling were based on recommendations of the U.S. Environmental Protection Agency (EPA) as contained in "Guideline on Air Quality Models (Revised)" (U.S. EPA, September 1990). The EPA SCREEN model (Brode 1988) was used to predict the maximum short-term (1-hour and 24-hour average) pollutant concentrations expected to occur in the vicinity of the power plant. The EPA Industrial Source Complex Long-Term (ISCLT) model (EPA 1986) was used to predict the annual average pollutant concentrations expected to occur within an 80 kilometer (km)(50 mile) radius of the power plant.[2]

3. DESCRIPTION OF THE COMPUTER MODELS USED

3.1 ISCLT

The ISCLT model is a computer program developed by the U.S. EPA for assessing the air quality impact of emissions from a variety of sources associated with an industrial source complex. The ISCLT model is a sector-averaged model that uses statistical wind summaries to calculate annual and seasonal average ground-level concentrations. The model uses either a Cartesian or polar coordinate receptor grid. The model uses the steady-state Gaussian plume equation for a continuous source to calculate ground-level concentrations. The generalized Briggs plume-rise equations are employed by the model. The model uses two equations, one developed by Huber and Snyder, and one developed by Scire and Schulman to evaluate the effects of aerodynamic wakes and eddies formed by buildings and other structures on plume dispersion. A wind profile exponent law is used to adjust the observed mean wind speed from the measurement height to the stack height for the plume rise and concentration calculations. The model accounts for variations in terrain height over the

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[2]The ISCLT model can be used to predict concentrations out to 100 km, however use of the model beyond 50 km is not recommended due to long plume transport times. Since a meso-scale model is not used as part of this study, a judgement was made to use the ISCLT results in the range 50 km-80 km as well.

receptor grid. The Pasquill-Gifford dispersion curves are used to calculate the vertical plume spread.

3.2 SCREEN

The SCREEN model uses the Gaussian plume equation to predict pollutant concentrations from a continuous source. It is assumed that the pollutants do not undergo any chemical reaction, and that no removal processes, such as wet or dry deposition, act on the plume during its transport from the source. SCREEN can perform single source, short-term calculations on point and area sources. The model gives results as predicted 1-hour average concentrations when flat or simple terrain is specified and 24-hour average concentrations for the complex terrain option (i.e. terrain higher than stack top).

The SCREEN model examines a full range of meteorological conditions to find maximum concentrations. Using full meteorology with the automated distance array, the SCREEN model provides the maximum concentration for each distance, and the highest concentration of the model run with its associated distance. The model can incorporate the effects of building downwash on plume dispersion, including the prediction of concentrations in the cavity region of a building wake. The model has the capability of predicting concentrations due to inversion breakup fumigation and shoreline fumigation.

4. DATA USED IN THE COMPUTER MODELING

4.1 SITE LOCATIONS

The Southeast Reference site is located in, what was to have been, the location of the Clinch River Breeder Reactor in Roane County, Tennessee. This location is on the north side of the Clinch River and is approximately 40 km west of Knoxville and 15 km south of Oak Ridge. The Southwest Reference site is that of the proposed, but never built, coal-fired New Mexico Generating Station (NMGS) in San Juan County, New Mexico - 55 km south of Farmington.

4.2 SOURCE CHARACTERISTICS

For the operation stage of energy production for a coal-fired power plant, there is one source of air emissions: the boiler stack. The source information needed to perform the air dispersion modeling includes the pollutant emission rate, stack height, exit gas temperature, exit gas velocity and stack tip (internal) diameter. The emissions used in the modeling are discussed in the next section.

It is assumed that the boiler is equipped with a wet lime/limestone scrubber and an electrostatic precipitator. The hypothetical coal-fired power plant was modeled with a stack height of 150 meters (m). The exhaust stack was modeled with an exit gas temperature of 325 Kelvin (52 degrees C). The exit gas flowrate was 740 actual cubic meters per second. This flowrate was input to the model as an exit gas velocity of 15 meters per second (50 feet per second) and an inside stack diameter of 7.9 meters.

4.3 EMISSIONS

Pollutant emissions used in this modeling analysis are given in Table 1. The pollutants of interest are NO_x, SO_2, total suspended particulate (TSP), PM_{10} (particulate matter with an aerodynamic diameter less than 10 micrometers), and metals, including: arsenic, cadmium, manganese, lead and selenium. NO_x and hydrocarbon emissions are employed in the ozone analysis in Part 2 of this document. Details describing the emissions estimates are given in Appendix A of ORNL/RFF (1994).

4.4 METEOROLOGY

Annual Average Concentrations

The meteorological data used in the air dispersion modeling of annual concentrations include STAR frequency summaries, ambient air temperature measurements and mixing height data.

Seasonal or annual STAR summaries are the principal meteorological inputs to the ISCLT model. A STAR summary is a tabulation of the joint frequency of occurrence of wind speed and wind direction categories, classified according to the Pasquill stability categories. The six wind speed categories used in the STAR summaries are defined as 0 to 3 knots, 4 to 6 knots, 7 to 10 knots, 11 to 16 knots, 17 to 21 knots and greater than 21 knots. The wind direction categories are the sixteen standard 22.5 degree sectors. The Pasquill stability categories are A through F.

STAR summaries for the Southeast Reference site were prepared from data collected near the site during the period 1985 to 1990 (1988 excluded). The meteorological tower is located approximately 4.5 km north of the proposed plant site. The anemometer height at the tower is 60 m.

Table 1. Controlled emission rates from the operation of the hypothetical 500 MW coal-fired power plant

	Emission rate for operation phase		
Pollutant	Tons/GWh	Tons/year	Grams/sec
Eastern Coal			
NO_x	2.90	9520	273.9
SO_2	1.74	5712	164.3
Hydrocarbon	0.06	210	6.0
TSP	0.15	485	14.0
PM_{10}	0.10	323	9.3
Western Coal			
NO_x	2.20	7236	208.2
SO_2	0.81	2660	76.5
Hydrocarbon	0.09	293	8.4
TSP	0.10	310	8.9
PM_{10}	0.06	207	6.0
Both Coals			
Arsenic	2×10^{-4}	0.66	1.9×10^{-2}
Cadmium	3×10^{-6}	0.01	2.9×10^{-4}
Manganese	1.3×10^{-4}	0.44	1.3×10^{-2}
Lead	9×10^{-5}	0.31	8.9×10^{-3}
Selenium	5×10^{-5}	0.17	4.9×10^{-3}

STAR summaries for the Southwest Reference site were prepared from data collected at Farmington, New Mexico, during the period 1954 to 1959. The anemometer height at the Farmington site was 10 meters.

Seasonal ambient temperatures from the meteorological station near the Southeast Reference site were used for the Southeast Reference site. Seasonal ambient temperatures for the Southwest Reference site were obtained from the National Weather Service Climatological Summary for Gallup, New Mexico. These temperatures were assigned to each stability category for use in the ISCLT model as recommended by the U.S. EPA (September 1990).

Mixing height data for both sites was obtained from Holtzworth's "Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States", 1972. These mixing heights were assigned to the six stability classes according to EPA (September 1990). The ISCLT model assumes that there is no restriction on vertical mixing during hours with E and F stabilities (default = 10000 m).

Short-term Average Concentrations

Short-term concentrations were calculated based on various "worst-case" meteorological conditions that could theoretically occur in the area. These worst-case conditions include:

- unstable atmospheric conditions/limited mixing;
- near-neutral atmospheric conditions/high winds; and
- stable atmospheric conditions.

These conditions were simulated in the SCREEN model using a combination of wind speed and Pasquill stability categories.

4.5 DISPERSION COEFFICIENTS

Rural dispersion coefficients were used for the ISCLT and SCREEN models. The selection of rural dispersion coefficients was based on a land use typing procedure, as recommended by the U.S. EPA (September 1990), to determine whether the characteristics of an area are primarily rural or urban.

4.6 MODELING GRID

A polar coordinate receptor grid was used in the ISCLT model to calculate annual average concentrations. The polar grid is defined by 10 concentric rings every 1 kilometer out to 10 kilometers and 14 concentric rings every 5 kilometers from 15 to 80 kilometers with 36 radials in 22.5 degree increments.

For predicting short-term average concentrations, a modeling grid was constructed along a single radial. The SCREEN model was used to determine short-term concentrations at 1 kilometer increments out to 10 kilometers and every 5 kilometers from 15 to 80 kilometers from the stack.

The effects of changes in terrain elevations within the vicinity of the plant sites are not accounted for in the air dispersion modeling. This dsimplification generally results in an underestimate of pollutant concentration close to the power plant, and an over-estimate at greater distances. This pattern is especially true if terrain is high in the vicinity of the plant.

5. RESULTS

The ISCLT model was run to predict annual average concentrations expected to occur in the vicinity of the power plant at 384 receptor locations (16 directions times 24 downwind distances). The highest concentration at each downwind distance is presented here for the sake of brevity. Results for each receptor location were used to derive a population-weighted concentration, for the health effects analysis, as described in ORNL/RFF (1994).

> ***The ISCLT model was run to predict annual average concentrations expected to occur in the vicinity of the power plant ...***

The SCREEN model was run to predict the highest 1-hr average concentrations expected to occur at 24 downwind distances from the power plant. One-hour concentrations predicted with the SCREEN model were multiplied by a persistence factor of 0.4 (Brode 1988) to obtain the highest 24-hour average concentration. Both models were run with an emission rate of 1 g/s. The results from these model runs represent the annual, 1-hr and 24-hr average concentrations expected to occur from a unit emission rate. Finally, these concentrations were multiplied by the emission rates, in grams per second, of each of the pollutants of interest. The SCREEN model predicts the highest concentration at each receptor along a single radial.

5.1 UNIT CONCENTRATIONS

The highest annual average unit concentration for 24 downwind distances, at the Southeast and Southwest Reference sites are presented in Table 2. These highest concentrations are informative for comparisons against National Ambient Air Quality Standards. In the calculation of fuel cycle impacts, however, the analysis does *not* use just the highest concentrations. Rather, the analysis uses estimates of concentrations that are calculated for a spatial grid of receptor locations. In the fuel cycle report (ORNL/RFF 1994), these concentrations are used with estimates of the population to derive population-weighted estimates of the increases in concentrations due to the power plant. As a point of reference, the highest of these concentrations for the Southeast site is 0.007 micrograms per cubic meter ($\mu g/m^3$), occurring 1 kilometer from the plant. The highest of these concentrations for the Southwest site is 0.005 $\mu g/m^3$, occurring 4 kilometers from the plant.

> ***... concentrations are used with estimates of the population to derive population-weighted estimates of the increases in concentrations ...***

The highest 24-hour and highest 1-hour average unit concentrations for 24 downwind distances are presented in the second and third columns of Table 2. At both sites, the highest 24-hour average concentration is 0.38 $\mu g/m^3$ and the highest 1-hour average concentration is 0.94 $\mu g/m^3$, both occurring 1 kilometer from the plant.

Differences in annual average unit concentrations (ISCLT) between the two sites are due to different meteorological conditions at each site.

5.2 POLLUTANT CONCENTRATIONS

The maximum pollutant concentrations of total suspended particulate (TSP), PM_{10}, NO_x, SO_2 and metals, predicted to occur at 24 downwind distances from the power plant at the Southeast site are presented in Table 3. The corresponding results for the Southwest site are presented in Table 4. These concentrations were determined by multiplying the unit concentrations in Table 2 by the controlled emission rate (grams per second) in Table 1 for each of the pollutants of interest. As emphasized in the previous section, the highest concentrations serve as a point of reference. The *concentrations computed at different locations* are the values used in the calculation of impacts in the fuel cycle analyses (ORNL/RFF 1994).

Table 2. Highest unit concentrations at downwind distances from the coal-fired power plant stack at the Southeast Reference site (micrograms/cubic meter)

Downwind Distance From Stack (km)	Highest Unit Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	0.375	0.938	0.007
2	0.299	0.748	0.004
3	0.227	0.566	0.005
4	0.182	0.456	0.005
5	0.161	0.403	0.005
6	0.160	0.400	0.005
7	0.148	0.371	0.004
8	0.135	0.337	0.004
9	0.123	0.307	0.004
10	0.113	0.282	0.004
15	0.104	0.260	0.003
20	0.086	0.216	0.003
25	0.072	0.179	0.003
30	0.061	0.153	0.002
35	0.054	0.134	0.002
40	0.048	0.119	0.002
45	0.043	0.108	0.002
50	0.039	0.098	0.002
55	0.026	0.065	0.002
60	0.024	0.060	0.001
65	0.022	0.056	0.001
70	0.022	0.055	0.001
75	0.021	0.053	0.001
80	0.021	0.052	0.001

Table 2. (cont'd) Highest unit concentrations at downwind distances from the coal-fired power plant stack at the Southwest Reference site (micrograms/cubic meter)

Downwind Distance From Stack (km)	Highest Unit Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	0.375	0.938	0.003
2	0.299	0.748	0.004
3	0.227	0.566	0.005
4	0.182	0.456	0.005
5	0.161	0.403	0.005
6	0.160	0.400	0.004
7	0.148	0.371	0.004
8	0.135	0.337	0.003
9	0.123	0.307	0.003
10	0.113	0.282	0.003
15	0.104	0.260	0.002
20	0.086	0.216	0.002
25	0.072	0.179	0.001
30	0.061	0.153	0.001
35	0.054	0.134	0.001
40	0.048	0.119	0.001
45	0.043	0.108	0.001
50	0.039	0.098	0.001
55	0.026	0.065	0.001
60	0.024	0.060	0.001
65	0.022	0.056	0.001
70	0.022	0.055	0.001
75	0.021	0.053	0.001
80	0.021	0.052	0.001

The highest annual average incremental concentration of PM_{10} at the Southeast and Southwest sites is 0.061 $\mu g/m^3$ and 0.032 $\mu g/m^3$ respectively. The highest annual average incremental concentration of SO_2 for the Southeast and Southwest sites is 1.08 $\mu g/m^3$ and 0.41 $\mu g/m^3$ respectively. The highest annual average incremental concentration of NO_x is 1.8 $\mu g/m^3$ and 1.1 $\mu g/m^3$ for the Southeast and Southwest sites respectively.

Annual average concentrations of arsenic, cadmium, manganese, lead and selenium are also given in Tables 3 and 4. The highest annual average arsenic concentration at both sites is 0.0001 $\mu g/m^3$. The highest annual average cadmium concentration at both sites is less than 0.0001 $\mu g/m^3$. The highest annual average manganese concentration at both sites is 0.0001 $\mu g/m^3$. The highest annual average lead concentration at the Southeast site is 0.0001 $\mu g/m^3$. Annual average lead concentrations at the Southwest site are less than 0.0001 $\mu g/m^3$. Annual average selenium concentrations at both sites are less than 0.0001 $\mu g/m^3$.

5.3 DEPOSITION

Potential deposition impacts due to dry deposition of TSP, PM_{10}, SO_2 emissions were determined. The deposition rates were determined from the product of the predicted concentration (mass per unit volume) and the particle deposition velocity. A dry particle deposition rate of 0.02 meters per second was used (California Air Resources Board 1987). The highest annual average dry deposition rate for SO_2 was calculated to be 0.022 micrograms per square meter per second ($\mu g/m^3$-s) for the Southeast site and 0.008 $\mu g/m^3$-s for the Southwest site. The corresponding values for TSP are 0.002 $\mu g/m^3$-s and 0.001 $\mu g/m^3$-s. The highest annual average dry deposition rate for PM_{10} is 0.001 $\mu g/m^3$-s for both sites. Since dry deposition rates were so small, no estimate was made of wet deposition, which is expected to be significantly lower than dry deposition.

5.4 COMPARISON TO NAAQS

Under current Federal law, National Ambient Air Quality Standards (NAAQS) have been established for sulfur dioxide, nitrogen dioxide, lead, carbon monoxide, ozone and inhalable particles (PM_{10}). Tables 5 and 6 present a comparison of the total concentration (the sum of the incremental concentration due to the power plant plus the background concentration) and the NAAQS for PM_{10}, NO_2 and SO_2, at both sites. As shown in Tables 5 and 6, the total ambient concentration of these pollutants is below the NAAQS. (For

Table 3. Highest pollutant concentration (micrograms/cubic meter) at downwind distances from the coal-fired power plant stack at the Southeast Site

Downwind Distance From Stack (km)	Highest TSP Concentration			Annual TSP Deposition (microgm/m²-s)	Highest PM_{10} Concentration			Annual PM_{10} Deposition (Microgm/m²-s)
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT		24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	
1	5.25	13.1	0.092	0.002	3.49	8.73	0.061	0.001
2	4.19	10.5	0.062	0.001	2.78	6.96	0.041	0.001
3	3.17	7.93	0.065	0.001	2.11	5.27	0.044	0.001
4	2.55	6.38	0.069	0.001	1.69	4.24	0.046	0.001
5	2.26	5.64	0.068	0.001	1.50	3.75	0.045	0.001
6	2.24	5.60	0.065	0.001	1.49	3.72	0.043	0.001
7	2.08	5.19	0.062	0.001	1.38	3.45	0.041	0.001
8	1.89	4.72	0.059	0.001	1.25	3.14	0.039	0.001
9	1.72	4.30	0.056	0.001	1.14	2.86	0.037	0.001
10	1.58	3.94	0.053	0.001	1.05	2.62	0.035	0.001
15	1.46	3.64	0.044	0.001	0.968	2.42	0.030	0.001
20	1.21	3.02	0.039	0.001	0.803	2.01	0.026	0.001
25	1.004	2.51	0.035	0.001	0.667	1.67	0.023	0.000
30	0.858	2.14	0.032	0.001	0.570	1.42	0.021	0.000
35	0.750	1.88	0.029	0.001	0.498	1.25	0.019	0.000
40	0.669	1.67	0.027	0.001	0.444	1.11	0.018	0.000
45	0.604	1.51	0.025	0.000	0.401	1.003	0.016	0.000
50	0.551	1.38	0.023	0.000	0.366	0.916	0.015	0.000
55	0.363	0.908	0.021	0.000	0.241	0.603	0.014	0.000
60	0.337	0.842	0.020	0.000	0.224	0.560	0.013	0.000
65	0.314	0.786	0.019	0.000	0.209	0.522	0.012	0.000
70	0.308	0.765	0.018	0.000	0.203	0.508	0.012	0.000
75	0.298	0.745	0.017	0.000	0.198	0.495	0.011	0.000
80	0.290	0.725	0.016	0.000	0.193	0.481	0.010	0.000

Annual Dry Deposition = Annual Concentration * 0.02 meters/second

Table 3. (cont'd)

Downwind Distance From Stack (km)	Highest TSP Concentration			Annual SO_2 Deposition (microgm/m^2-s)	Highest NO_x Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT		24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	61.7	154	1.08	0.022	103	257	1.80
2	49.2	123	0.731	0.0150	82.0	205	1.22
3	37.2	93.1	0.769	0.0150	62.1	155	1.28
4	29.9	74.9	0.804	0.016	49.9	125	1.34
5	26.5	66.2	0.797	0.016	44.2	110	1.33
6	26.3	65.7	0.765	0.015	43.8	109	1.28
7	24.4	60.9	0.727	0.015	40.6	102	1.21
8	22.2	55.4	0.689	0.014	37.0	92.4	1.15
9	20.2	50.5	0.656	0.013	33.6	84.1	1.09
10	18.5	46.3	0.627	0.013	30.8	77.1	1.04
15	17.1	42.7	0.521	0.010	28.5	71.2	0.869
20	14.2	35.5	0.458	0.009	23.7	59.1	0.764
25	11.8	29.5	0.411	0.008	19.6	49.1	0.685
30	10.1	25.2	0.374	0.007	16.8	42.0	0.623
35	8.81	22.0	0.341	0.007	14.7	36.7	0.568
40	7.85	19.6	0.313	0.008	13.1	32.7	0.523
45	7.09	17.7	0.289	0.006	11.8	29.6	0.482
50	6.47	16.2	0.268	0.005	10.8	27.0	0.447
55	4.26	10.7	0.249	0.005	7.11	17.8	0.416
60	3.95	9.89	0.233	0.005	6.59	16.5	0.389
65	3.69	9.23	0.219	0.004	6.15	15.4	0.364
70	3.59	8.98	0.205	0.004	5.99	15.0	0.342
75	3.50	8.74	0.194	0.004	5.83	14.6	0.323
80	3.40	8.50	0.183	0.004	5.67	14.2	0.305

Annual Dry Deposition = Annual Concentration * 0.02 meters/second

Table 3. (cont'd)

Downwind Distance From Stack (km)	Highest Arsenic Concentration			Highest Cadmium Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	0.0071	0.0178	0.0001	0.0001	0.0003	0.0000
2	0.0057	0.0142	0.0001	0.0001	0.0002	0.0000
3	0.0043	0.0138	00.0001	0.0001	0.0002	0.0000
4	0.0035	0.0087	0.0001	0.0001	0.0001	0.0000
5	0.0031	0.0077	0.0001	0.0000	0.0001	0.0000
6	0.0030	0.0076	0.0001	0.0000	0.0001	0.0000
7	0.0028	0.0070	0.0001	0.0000	0.0001	0.0000
8	0.0026	0.0064	0.0001	0.0000	0.0001	0.0000
9	0.0023	0.0058	0.0001	0.0000	0.0001	0.0000
10	0.0021	0.0053	0.0001	0.0000	0.0001	0.0000
15	0.0020	0.0049	0.0001	0.0000	0.0001	0.0000
20	0.0016	0.0041	0.0001	0.0000	0.0001	0.0000
25	0.0014	0.0034	0.0000	0.0000	0.0001	0.0000
30	0.0012	0.0029	0.0000	0.0000	0.0000	0.0000
35	0.0010	0.0025	0.0000	0.0000	0.0000	0.0000
40	0.0009	0.0023	0.0000	0.0000	0.0000	0.0000
45	0.0008	0.0021	0.0000	0.0000	0.0000	0.0000
50	0.0007	10.0019	0.0000	0.0000	0.0000	0.0000
55	0.0005	0.0012	0.0000	0.0000	0.0000	0.0000
60	0.0005	0.0011	0.0000	0.0000	0.0000	0.0000
65	0.0004	0.0011	0.0000	0.0000	0.0000	0.0000
70	0.0004	0.0010	0.0000	0.0000	0.0000	0.0000
75	0.0004	0.0010	0.0000	0.0000	0.0000	0.0000
80	0.0004	0.0010	0.0000	0.0000	0.0000	0.0000

Table 3. (cont'd)

Downwind Distance From Stack (km)	Highest Manganese Concentration			Highest Lead Concentration			Highest Selenium Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	0.0049	0.0122	0.0001	0.0033	0.0083	0.0001	0.0018	0.0046	0.0000
2	0.0039	0.0097	0.0001	0.0027	0.0067	0.0000	0.0015	0.0037	0.0000
3	0.0029	0.0074	0.0001	0.0020	0.0050	0.0000	0.0011	0.0028	0.0000
4	0.0024	0.0059	0.0001	0.0016	0.0041	0.0000	0.0009	0.0022	0.0000
5	0.0021	0.0052	0.0001	0.0014	0.0036	0.0000	0.0008	0.0020	0.0000
6	0.0021	0.0052	0.0001	0.0014	0.0036	0.0000	0.0008	0.0020	0.0000
7	0.0019	0.0048	0.0001	0.0013	0.0033	0.0000	0.0007	0.0018	0.0000
8	0.0018	0.0044	0.0001	0.0012	0.0030	0.0000	0.0007	0.0017	0.0000
9	0.0016	0.0040	0.0001	0.0011	0.0027	0.0000	0.0006	0.0015	0.0000
10	0.0015	0.0037	0.0001	0.0010	0.0025	0.0000	0.0006	0.0014	0.0000
15	0.0014	0.0034	0.0000	0.0009	0.0023	0.0000	0.0005	0.0013	0.0000
20	0.0011	0.0028	0.0000	0.0008	0.0019	0.0000	0.0004	0.0011	0.0000
25	0.0009	0.0023	0.0000	0.0006	0.0016	0.0000	0.0004	0.0009	0.0000
30	0.0008	0.0020	0.0000	0.0005	0.0014	0.0000	0.0003	0.0008	0.0000
35	0.0007	0.0017	0.0000	0.0005	0.0012	0.0000	0.0003	0.0007	0.0000
40	0.0006	0.0016	0.0000	0.0004	0.0011	0.0000	0.0002	0.0006	0.0000
45	0.0006	0.0014	0.0000	0.0004	0.0010	0.0000	0.0002	0.0005	0.0000
50	0.0005	10.0013	0.0000	0.0004	0.0009	0.0000	0.0002	0.0005	0.0000
55	0.0003	0.0008	0.0000	0.0002	0.0006	0.0000	0.0001	0.0003	0.0000
60	0.0003	0.0008	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
65	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
70	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
75	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
80	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000

Table 4. Highest pollutant concentration (micrograms/cubic meter) at downwind distances from the coal-fired power plant stack at the Southwest site

Downwind Distance From Stack (km)	Highest TSP Concentration			Annual TSP Deposition	Highest PM_{10} Concentration			Annual PM_{10} Deposition (microgm/m^2-s)
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT		24 hr Avg SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	
1	3.34	8.35	0.029	0.001	2.25	5.63	0.020	0.000
2	2.66	6.66	0.032	0.001	1.80	4.49	0.021	0.000
3	2.02	5.04	0.046	0.001	1.36	3.40	0.031	0.001
4	1.62	4.05	0.048	0.001	1.09	2.73	0.032	0.001
5	1.43	3.59	0.044	0.001	0.97	2.42	0.030	0.001
6	1.42	3.56	0.040	0.001	0.96	2.40	0.027	0.001
7	1.32	3.30	0.035	0.001	0.89	2.22	0.024	0.000
8	1.20	3.00	0.031	0.001	0.81	2.02	0.021	0.000
9	1.09	2.73	0.028	0.001	0.74	1.84	0.019	0.000
10	1.00	2.51	0.025	0.000	0.68	1.69	0.017	0.000
15	0.93	2.31	0.016	0.000	0.624	1.56	0.011	0.000
20	0.77	1.92	0.014	0.000	0.518	1.30	0.009	0.000
25	0.638	1.60	0.013	0.000	0.430	1.08	0.009	0.000
30	0.545	1.36	0.012	0.000	0.368	0.92	0.008	0.000
35	0.477	1.19	0.011	0.000	0.322	0.80	0.007	0.000
40	0.425	1.08	0.010	0.000	0.287	0.72	0.007	0.000
45	0.384	0.96	0.009	0.000	0.259	0.647	0.006	0.000
50	0.351	0.88	0.009	0.000	0.236	0.591	0.008	0.000
55	0.231	0.577	0.008	0.000	0.156	0.389	0.005	0.000
60	0.214	0.536	0.007	0.000	0.144	0.361	0.005	0.000
65	0.200	0.500	0.007	0.000	0.135	0.337	0.005	0.000
70	0.195	0.486	0.007	0.000	0.131	0.328	0.004	0.000
75	0.189	0.474	0.006	0.000	0.128	0.319	0.004	0.000
80	0.184	0.461	0.008	0.000	0.124	0.311	0.004	0.000

Annual Dry Deposition = Annual Concentration * 0.02 meters/second

Table 4. (cont'd)

Downwind Distance From Stack (km)	Highest SO_2 Concentration			Annual SO_2 Deposition (microgm/m^2-s)	Highest NO_x Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT		24 hr Avg SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	28.7	71.8	0.250	0.005	78.1	195	0.681
2	22.9	57.2	0.274	0.005	62.3	156	0.745
3	17.3	43.3	0.395	0.008	47.2	118	1.07
4	13.9	34.9	0.413	0.008	37.9	94.9	1.12
5	12.3	30.8	0.382	0.008	33.6	83.9	1.04
6	12.2	30.6	0.340	0.007	33.3	83.2	0.926
7	11.3	28.4	0.300	0.006	30.9	77.2	0.817
8	10.3	25.8	0.266	0.005	28.1	70.2	0.723
9	9.40	23.5	0.237	0.005	25.6	63.9	0.645
10	8.61	21.5	0.213	0.004	23.4	58.6	0.580
15	7.96	19.9	0.141	0.003	21.7	54.2	0.384
20	6.61	16.5	0.120	0.002	18.0	45.0	0.327
25	5.49	13.7	0.110	0.002	14.9	37.3	0.299
30	4.69	11.7	0.101	0.002	12.8	31.9	0.275
35	4.10	10.3	0.093	0.002	11.2	27.9	0.252
40	3.65	9.13	0.086	0.002	9.944	24.9	0.233
45	3.30	8.25	0.079	0.002	8.986	22.5	0.215
50	3.01	7.53	0.073	0.001	8.201	20.5	0.199
55	1.99	4.96	0.068	0.001	5.40	13.5	0.186
60	1.84	4.60	0.064	0.001	5.01	12.5	0.175
65	1.72	4.30	0.060	0.001	4.68	11.7	0.164
70	1.67	4.18	0.057	0.001	4.55	11.4	0.155
75	1.63	4.07	0.054	0.001	4.43	11.1	0.146
80	1.58	3.96	0.051	0.001	4.31	10.8	0.139

Annual Dry Deposition = Annual Concentration * 0.02 meters/second

Table 4. (cont'd)

Downwind Distance From Stack (km)	Highest Arsenic Concentration			Highest Cadmium Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	24 hr Avg SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	0.0071	0.0178	0.0001	0.0001	0.0003	0.0000
2	0.0057	0.0142	0.0001	0.0001	0.0002	0.0000
3	0.0043	0.0108	0.0001	0.0001	0.0002	0.0000
4	0.0035	0.0087	0.0001	0.0001	0.0001	0.0000
5	0.0031	0.0077	0.0001	0.0000	0.0001	0.0000
6	0.0030	0.0078	0.0001	0.0000	0.0001	0.0000
7	0.0028	0.0070	0.0001	0.0000	0.0001	0.0000
8	0.0026	0.0064	0.0001	0.0000	0.0001	0.0000
9	0.0023	0.0058	0.0001	0.0000	0.0001	0.0000
10	0.0021	0.0053	0.0001	0.0000	0.0001	0.0000
15	0.0020	0.0049	0.0000	0.0000	0.0001	0.0000
20	0.0016	0.0041	0.0000	0.0000	0.0001	0.0000
25	0.0014	0.0034	0.0000	0.0000	0.0001	0.0000
30	0.0012	0.0029	0.0000	0.0000	0.0000	0.0000
35	0.0010	0.0025	0.0000	0.0000	0.0000	0.0000
40	0.0009	0.0023	0.0000	0.0000	0.0000	0.0000
45	0.0008	0.0021	0.0000	0.0000	0.0000	0.0000
50	0.0007	0.0019	0.0000	0.0000	0.0000	0.0000
55	0.0005	0.0012	0.0000	0.0000	0.0000	0.0000
60	0.0005	0.0011	0.0000	0.0000	0.0000	0.0000
65	0.0004	0.0011	0.0000	0.0000	0.0000	0.0000
70	0.0004	0.0010	0.0000	0.0000	0.0000	0.0000
75	0.0004	0.0010	0.0000	0.0000	0.0000	0.0000
80	0.0004	0.0010	0.0000	0.0000	0.0000	0.0000

Table 4. (cont'd)

Downwind Distance From Stack (km)	Highest Manganese Concentration			Highest Lead Concentration			Highest Selenium Concentration		
	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT	24 hr Avg. SCREEN	1 hr Avg. SCREEN	Annual Avg. ISCLT
1	0.0049	0.0122	0.0000	0.0033	0.0083	0.0000	0.0018	0.0046	0.0000
2	0.0039	0.0097	0.0000	0.0027	0.0067	0.0000	0.0015	0.0037	0.0000
3	0.0029	0.0074	0.0001	0.0020	0.0050	0.0000	0.0011	0.0028	0.0000
4	0.0024	0.0059	0.0001	0.0016	0.0041	0.0000	0.0009	0.0022	0.0000
5	0.0021	0.0052	0.0001	0.0014	0.0036	0.0000	0.0008	0.0020	0.0000
6	0.0021	0.0052	0.0001	0.0014	0.0036	0.0000	0.0008	0.0020	0.0000
7	0.0019	0.0048	0.0001	0.0013	0.0033	0.0000	0.0007	0.0018	0.0000
8	0.0018	0.0044	0.0000	0.0012	0.0030	0.0000	0.0007	0.0017	0.0000
9	0.0016	0.0040	0.0000	0.0011	0.0027	0.0000	0.0006	0.0015	0.0000
10	0.0015	0.0037	0.0000	0.0010	0.0025	0.0000	0.0006	0.0014	0.0000
15	0.0014	0.0034	0.0000	0.0009	0.0023	0.0000	0.0005	0.0013	0.0000
20	0.0011	0.0028	0.0000	0.0008	0.0019	0.0000	0.0004	0.0011	0.0000
25	0.0009	0.0023	0.0000	0.0006	0.0016	0.0000	0.0004	0.0009	0.0000
30	0.0008	0.0020	0.0000	0.0005	0.0014	0.0000	0.0003	0.0008	0.0000
35	0.0007	0.0017	0.0000	0.0005	0.0012	0.0000	0.0003	0.0007	0.0000
40	0.0006	0.0016	0.0000	0.0004	0.0011	0.0000	0.0002	0.0006	0.0000
45	0.0006	0.0014	0.0000	0.0004	0.0010	0.0000	0.0002	0.0005	0.0000
50	0.0005	10.0013	0.0000	0.0004	0.0009	0.0000	0.0002	0.0005	0.0000
55	0.0003	0.0008	0.0000	0.0002	0.0006	0.0000	0.0001	0.0003	0.0000
60	0.0003	0.0008	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
65	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
70	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
75	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000
80	0.0003	0.0007	0.0000	0.0002	0.0005	0.0000	0.0001	0.0003	0.0000

regulatory purposes the highest, second highest receptor concentration is added to the background concentration and compared to the NAAQS).

The quarterly average NAAQS for lead is 1.5 $\mu g/m^3$. The highest quarterly average incremental concentration of lead, due to the power plant, is 0.0001 $\mu g/m^3$ at both sites. The background concentration of lead was not available at either site.

Table 5. Summary of modeling results and monitoring data for a coal-fired boiler located at the Southeast Reference site (micrograms per cubic meter)

	Particulate		PM_{10}		NO_x	SO_2	
Highest Incremental Impact of the Facility	5.3	0.092	3.5	0.061	1.8	62	1.08
Background Concentration*	108	47	71	37	23	76	25
Total Concentration	113	47	74	37	25	138	26
Primary NAAQS**	None	None	150	50	100	365	80

*From 1990 EPA AIRS database McMinn Co., TN monitoring station (Site I.D. 47-107-0101); 2nd highest 24 hour average and annual mean.

**For regulatory purposes the highest second highest receptor concentration is added to the baseline concentration and compared to the National Ambient Air Quality Standard (NAAQS).

Table 6. Summary of modeling results and monitoring data for a coal-fired boiler located at the Southwest Reference site (micrograms per cubic meter)

	Particulate		PM_{10}		NO_x	SO_2	
	24 hour	Annual	24 hour	Annual	Annual	24 hour	Annual
Highest Incremental Impact of the Facility	3.3	0.048	2.3	0.032	1.12	29	0.41
Background Concentration*	66	42?	64	24	15	93	14
Total Concentration	69	42	66	24	16	122	14
Primary NAAQS**	None	None	150	50	100	365	80

*From 1991 EPA AIRS database San Juan Co., NM monitoring stations; 2nd highest 24 hour average and annual mean concentrations.

**For regulatory purposes the highest second highest receptor concentration is added to the baseline concentration and compared to the National Ambient Air Quality Standard (NAAQS).

?Indicates that the mean does not satisfy AIRS summary criteria.

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