DRY DEPOSITION OF GASEOUS POLLUTANTS FROM COAL-FIRED POWER PLANTS

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Field tests of a system to determine deposition resistances of specific pollutants and the eddy diffusivity for pollutants in the surface layer have been conducted, and the data have been analyzed. The results add considerably to the data base available for study of pollutant dry removal processes.

Since the Northwest's coal deposits represent a significant part of national energy reserves, studies of the natural dry removal processes of the air pollutants associated with emissions from coal-fired fossil fuel power plants are being conducted in increasing numbers. This study is designed to provide quantitative information for air pollutant modeling needs through in situ measurements of the dry removal rates of pollutants. The current objective is to provide a data base both for modeling dry deposition of specific pollutants (SO_2, O_3, NO_x, NO) and atmospheric pollutant transport processes by defining deposition resistances of specific pollutants and the appropriate eddy diffusivity for pollutants in the surface layer.

FIELD TESTS

Ozone was selected for intensive study for two reasons: 1) it is of considerable interest as a secondary pollutant from fossil fuel plants, and 2) unlike the other pollutants, the flux of ozone in the surface layer can be measured by both the gradient and eddy flux methods using current instrumentation. The deposition of SO_2 and other gaseous pollutants will also be determined to allow generalization of the results.

As indicated by an earlier study,[25] a mobile probe, using a high-flow Teflon intake line, is the best method of measuring ozone gradient. An automated dual line profile system was assembled for this experiment, and is shown in Figure 1.10 as it operated for ozone. Pollutant concentrations are sampled at predetermined heights on the "Roving Intake Tower." Since the dual intake system is designed to use two pollutant monitors simultaneously, any differences in the sensitivity of the monitors may be compensated for by switching the intake line positions at regular intervals determined largely by the monitor response times. The roving intake instrumentation assembled for these studies is designed to allow simultaneous measure of the dry removal rates of O_3, SO_2, NO_x and NO. The system can be used with other pollutant monitors that have a sufficiently fast, real-time response.

The ambient meteorological conditions are recorded from sensors on the "Profile Tower." The ozone direct flux measurement system consists of a high-flow Teflon sample line with a fixed input at the Gill anemometer on the top of the Profile Tower. The ozone and wind components time series are recorded at this height.

FIELD TEST RESULTS

A field test of instrumentation systems to detect sulfur compounds and ozone has been completed, and the data have been analyzed. The site near Yelm, WA, an abandoned farm field with a grass cover 6-8 in. high, was in the downwind region of the anticipated plume of the coal-fired power plant at Centralia, WA.

Results from filter samples indicated measurable sulfur aerosols only marginally above normal filter background concentrations. The SO_2 concentrations were very low, below or at the threshold of the SO_2 monitor during the entire field deployment period. Ozone concentrations were generally at background levels and were readily measurable by the O_3 monitor.

Summaries of the ozone dry deposition results at the Yelm site in terms of deposition velocities defined using ozone concentration values at 30 ft are given in Table 1.10. The experiments are coded as direct eddy flux compilation (F) and gradient flux compilation (G). These results are given in terms of resistance values in Table 1.11.

DISCUSSION

The reasonable consistency of the gradient and eddy flux determinations of ozone fluxes supports the validity of the methods, although further analysis is necessary to define implications for pollutant flux mechanisms. These results represent a considerable addition to the data base available for study of pollutant dry removal processes. Ozone flux rates for the near background concentrations had deposition velocities in the range 0.2 to 0.6 cm/sec.

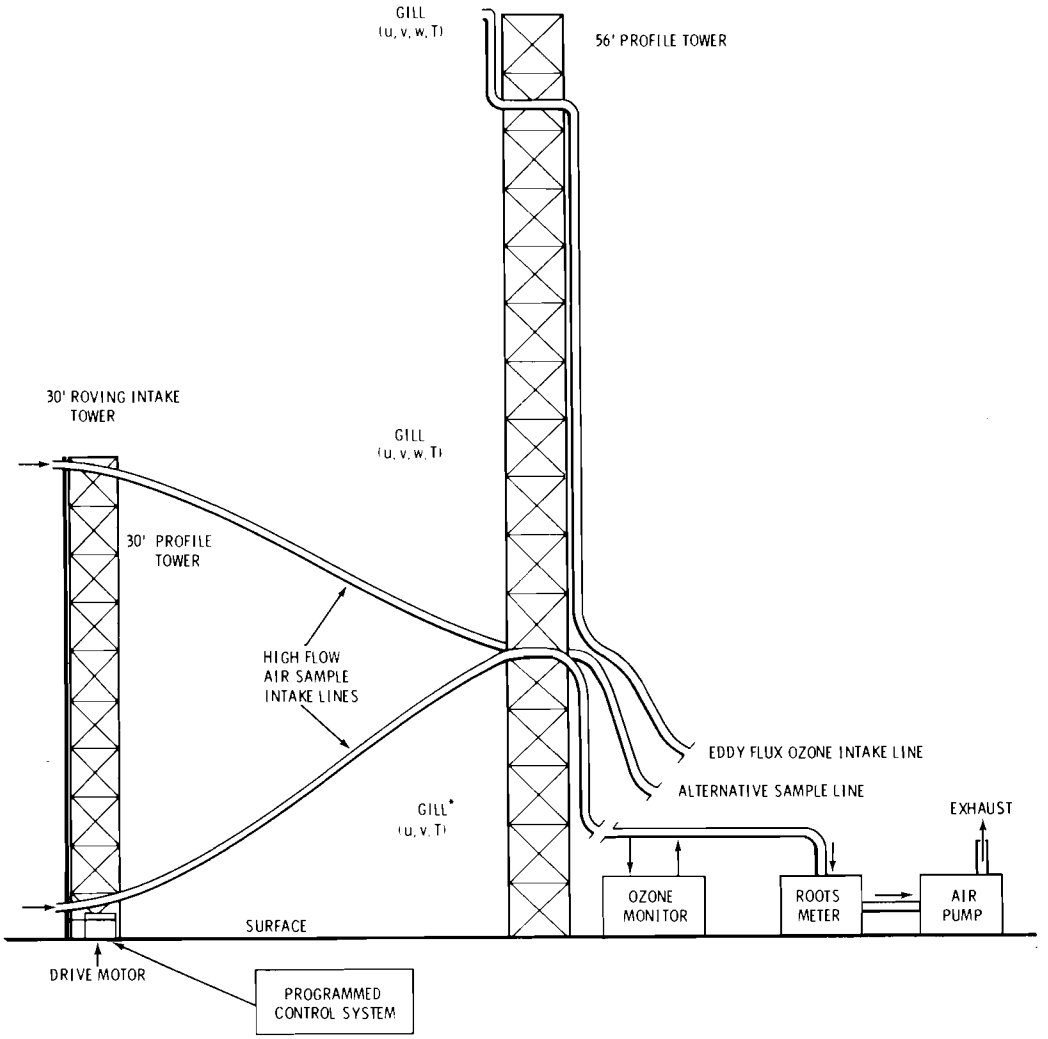

FIGURE 1.10. Pollutant Profiler Configuration for Ozone

TABLE 1.10. Summary of Ozone Dry Deposition Results at Yelm Site, F = Eddy Correlation Method, G = Gradient Method.

Test No.	Date	Time (min)	Method	V_d cm/s	V_m cm/s	u (15m) m/s	R_l (15m)
1	6/9/77	1245-1330(45)	F	0.27	2.3	6.3	-0.085
2	6/9/77	1330-1415(45)	F	0.52	1.5	6.1	-0.10
3	6/9/77	1415-1513(59)	F	0.64	2.1	5.7	-0.11
4	6/9/77	1715-1810(55)	G	0.35	1.8	5.5	-0.09
5	6/9/77	1811-1909(58)	G	0.16	1.3	5.1	0.15
6	6/9/77	1911-2011(60)	G	0.40	4.0	3.9	0.24

TABLE 1.11. Resistance Values for Ozone Dry Deposition Results at Yelm Site, R_T = Total Resistance, R_a = Aerodynamic Resistance and R_s is the Apparent Surface Resistance (= R_T - R_a).

Test No.	R_T s/cm	R_a[(a)] s/cm	R_s s/cm
1	3.7	0.43	3.3
2	1.92	0.66	1.3
3	1.56	0.48	1.1
4	2.85	0.56	2.3
5	6.25	0.77	5.4
6	2.50	0.25	2.3

[(a)] R_a is assumed to be inverse of V_m.

The "surface resistances" in Table 1.11 are only the difference between the total momentum flux and the pollutant flux resistances. These differences may be a true surface difference or they may variously reflect differences in atmospheric transport processes between ozone and momentum. The recommended application is to determine the dry deposition flux rates of a number of gaseous pollutants along with ozone flux by both the eddy and gradient methods. This is to provide relative gaseous pollutant deposition rates with a direct determination of the eddy diffusivity for ozone. This will provide a data base for determination of the nature of the apparent surface resistances.

THE DEPENDENCE OF DEPOSITION VELOCITY ON DISTANCE DOWNWIND OF A POINT SOURCE OF ATMOSPHERIC CONTAMINATION

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The surface depletion model was used to demonstrate that the deposition velocity for a reference height of 1 m is, for practical purposes, independent of downwind distance for an elevated ($h \geq 2$ m) point-source release of atmospheric contamination. This was not found to be the case for a surface source (h=o).

Dry deposition can cause a significant loss of material from a diffusing plume of atmospheric contamination. The downward flux of material due to deposition is commonly parameterized as a deposition velocity v_d multiplied by the air concentration χ measured at some reference height z_d,

$$F_d = - v_d \chi(z_d).$$

Therefore, if a vertical gradient of contamination exists, as is usually the case for a diffusing substance, the deposition velocity will be a function of the reference height.[26]

The deposition velocity parameterization is most useful if v_d depends only on the meteorological conditions, the properties of the contaminant, and the nature of the deposition surface and, thus, is independent of distance from the source. The vertical concentration gradient, however, reflects two processes: diffusion away from the source of contamination and diffusion towards the deposition surface. The deposition velocity will be independent of distance from the source only if the vertical contaminant profile between the surface and the deposition reference height is controlled solely by the deposition flux and does not depend on diffusion away from the source of contamination.

For a nondepositing material, there is no vertical flux at z=o, and hence the vertical gradient at the surface is equal to zero. This condition is also closely approximated within a finite layer whose depth increases with downwind distance x. For a depositing material, therefore, deposition alone will determine the vertical gradient up to a height which increases with x. Equivalently, deposition will determine the vertical gradient below z_d only beyond a specific downwind distance.

A practical choice for a deposition reference height is 1 m. The surface depletion model[27] was consequently used to investigate the ratio $\chi(1m)/\chi(1cm)$ for a depositing material, assuming a reference height of 1 cm gave a deposition velocity independent of downwind distance. The distance $x_{1\%}$ was found, beyond which the ratio $\chi(1m)/\chi(1cm)$ is within 1% of its asymptotic value at large x. Beyond $x_{1\%}$ deposition is the dominant process in the lowest 1 m. As expected $x_{1\%}$ was also found to be the distance at which $\chi(1m)/\chi(1cm)$ without deposition was within 1% of unity.

More important, it was found that for an elevated release, $h \geq 2m$, essentially all of the deposition occurs beyond $x_{1\%}$. Hence, for practical purposes, the deposition velocity at a height of 1 m is independent of downwind distance for an elevated release.

This was not found to be the case for a surface release, however. In this case the ratio $\chi(1m)/\chi(1cm)$ is negative for a large distance downwind, and significant deposition occurs before the ratio reaches the positive asymptotic value indicating dominance of the deposition process in determining the vertical profile.