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The Location and Magnitude of Maximum Short-Term Ground Level Impacts of Effluents from Tall Stacks

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Introduction

The 3-hour national ambient air quality standard for SO_2 requires that at any point, the SO_2 concentration not exceed 0.5 ppm (1300 ug/m^3) more than once per year. This standard poses the need to adequately assess such maximum short-term impacts. This paper focuses on assessment of the short-term impacts of SO_2 sources with tall stacks (stack heights greater than 100 m).

The original intent of building tall stacks for sources of large SO_2 emissions potential was to reduce the maximum ground-level ambient air quality impacts of the stack's effluent, the theory being that the effluent's ambient concentration (mass/unit volume) would be reduced by spreading the same amount of pollutant mass through a greater atmospheric volume. However, there have been conflicting opinions on how successful tall stacks have actually been in reducing maximum ground-level impacts. These differences in opinion center about the expected location and magnitude of maximum short-term ground level impacts of effluents from tall stacks.

The purpose of this paper is to review the data relevant to the assessment of the location and magnitude of maximum short-term impacts of effluents from tall stacks. The questions this investigation seeks to answer are: 1) At what distance from a tall stack is its maximum short-term impact observed? 2) What atmospheric conditions are associated with the occurrence of maximum short-term impacts? and 3) Which, of various dispersion coefficients when used in standardly available models, best estimate the locations and magnitudes of expected maximum short-term impacts of effluents from tall stacks?

Procedure

Because theory is born out by observation, answers derived from the pertinent observations are preferred to those based purely on theory. In order to avoid observational bias, sufficient and necessary observations must be evaluated; that is, the temporal and spatial characteristics of the observations must be considered. It must also be determined that the observations are not biased by the manner in which they are made.

In order to adequately assess the distance from the stacks to short-term maximum impacts, it would be desirable to obtain quality assured data from a network consisting of continuous monitors at numerous distances along each of numerous radials extending in different directions from the stack. The monitors should be located so that they adequately cover both near (less than 2 km) and far field distances from the stack with a spatial density sufficient to determine the distance to maximum impact. Ideally the source(s) to be analyzed would be isolated such that background contributions to the pollutant concentrations being monitored are minimized. Furthermore, it would be desirable that the period of record of observations extend over several years so that year to year variations in meteorological extremes may also be accounted for. The longer the period of record and the greater the monitoring spatial density, the greater the probability that occurrences of worst case meteorological conditions and the constraining emission characteristics of the source will coincide so that concentrations representative of maximum short-term impacts of effluents from tall stacks can be observed by a monitor.

Obviously if the effluent characteristics of the stack are dependent on or controlled as a function of expected meteorological conditions (i.e., by Supplementary Control Systems (SCS), sometimes referred to as dynamic emission control systems, or emissions limit control systems, etc.), the probability of observing short-term maximum impacts may be greatly reduced. Therefore, a monitoring network might not observe the maximum possible short-term concentration if tall stack effluents are controlled by a correctly designed and properly operating SCS application or similar meteorology dependent emission control technique.

Upon determining the periods of observed maximum short-term impact, the meteorological conditions associated with those periods can also be determined.

Upon determining the location, magnitude, and meteorological conditions associated with maximum observed short-term impacts, it is then possible to compare model calculated locations and magnitudes of maximum short-term impacts with observations. Such comparisons may be used to assess which model results best compare with observations, but cannot necessarily be used to conclude that the transport and dispersion of the effluent mass is accurately modeled with respect to the actual atmospheric cause-effect relationships. In order to evaluate and compare the adequacy of a model with respect to accurately accounting for plume rise, transport, and dispersion of the pollutant mass, detailed and comprehensive observations of such factors would be required.

In order to determine if a model is satisfactorily performing from a regulatory perspective, comparisons with observations are made with respect to the upper ends of the frequency distributions of predictions and observations. This comparison is called for, particularly in light of the requirements of the short-term ambient air quality standard which is based on the upper end of the frequency distribution of observations. That is, violations of the ambient air quality standards (e.g., the 3-hour SO_2 standard) are determined by the observation of more than one occurrence per year of concentrations exceeding a set maximum.

Observations

The first observation to be made is that there is no monitoring network available which ideally provides all the observational desires previously set forth. However, of the limited data available, there appears to be a set of observations from a monitoring network in the vicinity of the tall stacks of the Muskingum River Power Plant operated by the Ohio Power Company of the American Electric Power System, which comes closest to satisfying observational requirements. The data from the Muskingum River Power Plant's SO_2 monitoring network is relied upon for the determination of the distance from the stacks to maximum short-term (3-hour) SO_2 impacts of effluents from tall stacks. Once the distance to maximum 3-hour SO_2 impacts is determined, data from monitors which are located at comparable distances to other tall stack sources can also be evaluated with respect to the magnitude of maximum 3-hour SO_2 impacts.

The Muskingum River Power Plant is located in Washington County in southeastern Ohio in the valley formed by the Muskingum River. The terrain in the vicinity of the plant is hilly with elevations as high as 350 m above mean sea level (150 m above the base of the plant stacks). The total generation capacity of the Muskingum River Power Plant facility is approximately 1,500 megawatts. The current sulfur content of the coal fired averages about

9 to 10 lb $SO_2/10^6$ Btu. No flue gas desulfurization system is employed and the effluent is emitted through two separate 252 m stacks. The combined SO_2 emission rate from the two stacks when the plant is operating at full load is approximately 15,500 g/s or 62 tons/hr (assuming 9 lb $SO_2/10^6$ Btu coal fired).

Distance to Maximum Short-Term Impacts

Since January 1978, four continuous SO_2 monitors have been in location along a radial extending in a northeasterly direction from the Muskingum River Power Plant. Table I identifies the Muskingum River Power Plant SO_2 monitoring sites and their locations. It can be seen that the closest monitor, the Center Bend monitor, is 1.7 km from the centroid of the two stacks.

Table I. Muskingum River Power Plant SO_2 monitors.

Monitor Name	Monitor No.	Distance from Stacks[a] (km)	Azimuth from Stacks[a] (°)	Height above Stack Base (m)
Center Bend	5	1.7	37	74
Hackney	2	4.6	41	74
Rich Valley	3	8.5	36	105
Caldwell	4	20.7	33	132
Beverly	1	5.2	138	56
Mount Olivet	6	6.1	240	108

[a] Stacks 1 and 2 are located 645 m apart along a 240° azimuth. Distances and azimuths indicated are from the centroid of the two stacks.

Because four of these monitors are located within 4° of a straight line (37°) radial from the source of emissions, it may be assumed that all four monitors on occasion will be simultaneously impacted by emissions from the plant (i.e., when the mean transport winds are from the SW (217°)). Because these four monitors are located in the same downwind direction from the plant, it was assumed that data from this array of monitors were sufficient to determine the distance to highest observed impacts.

Table II lists the three highest observed 3-hour concentrations at each monitor since January 1978 and the dates of those occurrences at each monitor. It can be seen that the highest 3-hour concentration ever observed at any of these four monitors occurred at the monitor closest to the plant on May 5, 1979. It can also be seen that the highest 3-hour concentration observed at the monitor next closest to the plant also occurred on May 5, 1979.

Meteorology Associated with Maximum Short-Term Impacts

Table II also presents the meteorological conditions associated with the monitored concentrations. It can be seen that the highest 3-hour SO_2 impact occurred in the afternoon under conditions associated with very unstable atmospheric conditions; that is, very light wind speeds (less than 1.5 m/s), clear skies, and a well developed mixed layer (inversion base 1300 m above ground level). Thus, the maximum 3-hour SO_2 concentration measured by the Muskingum River Power Plant monitoring network was measured at the monitor closest to the stacks, and occurred under very unstable atmospheric conditions.

Table II. SO_2 concentrations and meteorological observations during highest 3-hour SO_2 measurements (wind speed measured on-site; cloud cover and mixing height measured at Huntington, WV).

Monitor of Concern, Dates of Highest Measurements at Monitor of Concern (Mo/Day/Yr)	Highest Measured 3-Hour SO_2 Concentration During Day (ppm)				Hours of Measurement at Monitor of Concern	Wind Speed (mph)	Opaque Cloud Cover (tenths)	Afternoon Mixing Height (m)
	Monitor 5	Monitor 2	Monitor 3	Monitor 4				
Monitor 5 (1.7 km)								
5/5/79	.63	.40	.28	.19	13-15	2-3	0	1300
5/22/79	.41	.22	.07	.01	14-16	3-4	6-10	2350
9/5/78	.39	.31	.08	.01	14-16	1-2	0	850
Monitor 2 (4.6 km)								
5/5/79	.63	.40	.28	.19	14-16	2-3	0	1300
9/6/78	.13	.32	.34	.51	12-14	3-4	0-3	1300
11/19/78	.18	.31	.24	.22	15-17	1-2	0-10	660
Monitor 3 (8.5 km)								
6/4/79	.17	.11	.40	.05	3-5	1-4	10	N/A
6/15/79	.14	.24	.40	.23	10-12	7-8	0	1600
9/6/78	.13	.32	.34	.51	12-14	3-4	0-3	1300
Monitor 4 (20.7 km)								
9/6/78	.13	.32	.34	.51	13-15	3-5	0-3	1300
6/15/79	.14	.24	.40	.23	11-13	5-8	0	1600
11/19/78	.18	.31	.24	.22	18-20	0-3	5-10	660

The maximum impacts observed at monitors located at greater distances from the power plant occurred during periods of higher wind speeds and/or more stable atmospheric conditions. It should also be noted that these more distant monitors, monitors 3 and 4, are higher in elevation than monitors 5 and 2, and therefore closer to plume height. If the monitors were located at lower elevations, they would be expected to observe lower concentrations than those measured at the higher elevations.

Because it is observed that maximum short-term concentrations occur close to a source with tall stacks, other sources with quality assured monitors close to their tall stacks also warrant review. In addition to the Muskingum River Power Plant, there are three Tennessee Valley Authority (TVA) power plants which were found to have quality assured continuous SO_2 monitors close to their tall stacks. Table III lists these four power plants with quality assured continuous SO_2 monitors within 2 km of their tall stacks. Table IV lists the stack design and full load operating parameters and emission rates for the power plants identified in Table III.

Although there are no other continuous monitors along the same radial from the stack for the TVA monitors, and thus no means of further assessing the distance to maximum impact at these plants, the meteorological conditions associated with the occurrences of maximum short-term impacts at these monitors can be further evaluated. It is observed upon review of the meteorological data during periods of measured maximum short-term SO_2 concentrations, that conditions generally consisted of those associated with very unstable atmospheric conditions; i.e., very light and variable winds, clear skies, and well developed mixing layers, which occurred during the late morning and afternoon periods.

Thus, the modeling of maximum 3-hour SO_2 concentrations resulting from tall stack effluents should be approximated by the transport and dispersion processes associated with very unstable atmospheric conditions. Although such transport and dispersion processes have not necessarily been adequately observed and understood, Gaussian air quality models which account for the occurrence of very unstable atmospheric conditions by use of stability dependent dispersion coefficients have traditionally been used to estimate air quality impacts. Pasquill-Gifford class A stability dispersion coefficients[1] are one of the sets of coefficients that have been used by regulatory agencies and others in modeling tall stack effluent impacts under very unstable atmospheric conditions.

Because a controversy has existed regarding the use of the Pasquill-Gifford (P-G) curves for class A (very unstable) atmospheric conditions in estimating ground level pollutant impacts from tall stacks,[2] the sets of dispersion coefficient curves to be considered herein will include the P-G class A curves and the curves derived from field studies for which tracers were released at heights of 100 m or higher. The P-G class B curves are considered because several investigators have suggested that replacing the P-G A curves with the P-G class B curves would yield a better comparison of maximum calculated with maximum measured impacts. The contention being that the P-G class A curves when used with standardly available models (such as the U.S. EPA CRSTER or MPTER models) result in overestimates of ground level impacts and that these impacts are calculated to occur too close to the stack for sources having tall stacks.

Table III. Power plants with quality assured SO_2 monitors within 2 km of their tall stacks.

Power Plant	Location (County, State)	Monitor Number	Monitor Distance from Stacks (km)	Monitor Azimuth from Stacks (°)	Monitor Height above Stack Base (m)
Muskingum River	Washington, Ohio	5	1.7	37	74
John Sevier	Hawkins, TN	4	1.6	229	9
Widows Creek	Jackson, AL	24	1.6	139	4
Cumberland	Stewart, TN	6	1.8	97	26

Table IV. Stack design and full load operating parameters and SO_2 emission rates.

Power Plant	Unit Number	Stack Number	Stack Height (m)	Stack Diameter (m)	Stack Exit Velocity (m/s)	Stack Exit Temperature (°K)	Emission Rate (g/s)
Muskingum River	1-4	1	252	7.6	34.5	430	9,400
	5	2	252	6.7	23.2	425	6,100
John Sevier	1-2	1	107	7.2	12.3	412	1,900
	3-4	2	107	7.2	12.3	412	1,900
Widows Creek	1-6	1	305	8.2	28.1	422	1,700
	7	2	152	6.3	28.1	399	4,900
	8	3	152	7.4	22.7	367	700
Cumberland	1	1	305	9.5	32.9	422	10,500
	2	2	305	9.5	32.9	422	10,500

Three independent sets of field experiments have been found in the literature which investigate the dispersion of tracers released at heights of 100 m and higher under very unstable atmospheric conditions. Singer and Smith,[3] Vogt, et al.,[4] and Thomas, et al.,[5] have derived σ_y and σ_z curves based on such field investigations. Table V identifies the curves of dispersion coefficients considered herein. This table indicates the investigator, experiment site, tracer release height, and surface roughness length (z_0) for each set of curves considered.

Figures 1 and 2 graphically present the curves of σ_y and σ_z, respectively, for each of the tracer studies identified in Table V.[6]

Analyses of Periods of High Short-Term Impacts at Monitors Near Tall Stacks

Table VI indicates the highest 3-hour SO_2 concentrations observed under very unstable atmospheric conditions at each of the monitors located within 2 km of the power plants identified in Table IV. Table VI also compares the observed values with the concentrations calculated using the alternative sets of dispersion coefficient curves. Calculated values are based on the use of: on-site meteorological data, assumed full load operating conditions (for each stack in operation at the time), Briggs plume rise,[7] and steady state Gaussian dispersion assuming co-located stacks and an unlimited mixing height (because no on-site measurements of mixing layer depth or actual plume height were available). The calculated 3-hour concentrations are the average of three 1-hour calculations. It should be noted that experience shows higher impacts are calculated at full load under unstable atmospheric conditions than for reduced load operating conditions. Furthermore, background concentrations were found to be negligible during these periods based on upwind observations.

It can be seen from Table VI that all the calculated concentrations resulting from the use of each of the alternative sets of dispersion coefficients underpredict the observed 3-hour average values at each monitoring site. Calculations based on the use of the P-G A and Karlsruhe A curves, however, appear to best approximate observations. It should be noted, although not directly shown, that even if the mixing layer was assumed to be equal to plume height, the 3-hour average concentration would still be underpredicted by use of the P-G B, BNL B_2 and Jülich A curves. Furthermore, analyses have also shown that even if it is assumed that the mean wind blew continually in the direction of the monitor, the concentrations calculated by use of the P-G B, BNL B_2, and Julich A curves still underpredict observations.[8]

Obviously the comparisons made in Table VI do not necessarily consider the upper ends of the frequency distributions of predicted and observed concentrations (to be addressed later herein) as recommended in the "Guideline on Air Quality Models."[9] However, Table VI does provide an example of the comparative ranking of the impacts calculated at select monitoring sites using the alternative sets of dispersion coefficient curves.

The relative calculated impacts using the alternative sets of dispersion coefficient curves can also be demonstrated graphically and are depicted by Figures 3 and 4.

Table V. Curves of dispersion coefficients (σ_y and σ_z) from field experiments.

Curve	Investigator	Experiment Site	Tracer Release Height (m)	Surface Roughness Length, z_0 (m)
P-G A	Pasquill-Gifford	O'Neill, Nebraska	< 1	≤ 0.03
P-G B	Pasquill-Gifford	O'Neill, Nebraska	< 1	≤ 0.03
BNL B_2 [a]	Singer-Smith	Long Island, NY	≥ 100	≈ 1
Jülich A	Vogt et al.	Julich, W. Germany	≥ 100	≈ 1
Karlsruhe A [b]	Thomas et al.	Karlsruhe, W. Germany	≥ 195	≈ 1

a No σ_y or σ_z curves have been derived by Singer and Smith for the most unstable category of atmospheric conditions observed at the Brookhaven National Laboratory (BNL) experiment site on Long Island, NY. Singer and Smith indicate stability categories A, B_2, B_1, C, and D based on wind direction traces (A represents most unstable and D represents most stable; i.e., A is more unstable than B_2).[3] Curves were derived only for categories B_2, B_1, C, and D.[6]

b Sets of σ_y and σ_z curves have also be developed for lower tracer release heights at Karlsruhe, only the curves for the highest tracer release heights (closest to the plume heights of tall stack effluents) are reviewed herein.

Table VI. Comparison of observed and calculated SO_2 concentrations at the closest monitor to each power plant. (Observed concentrations include background SO_2 concentrations, calculated values do not. Background concentrations for each period analyzed are estimated not to exceed 0.02 ppm.)

			3-Hour SO_2 Concentration (ppm)					
				Calculated				
Power Plant	Date	Hours	Observed	P-G A	P-G B	BNL_2	Jülich A	Karlsruhe A
Muskingum River	5/5/79	13-15	.63	≤ .47	.00	.00	≤ .01	≤ .49
John Sevier	3/25/77	15-17	.43	.22	.00	.06	.12	.11
Widows Creek	9/20/78	12-14	.28	.20	.00	.04	.08	.11
Cumberland	10/22/77	15-17	.21	.05	.00	.00	.00	.05

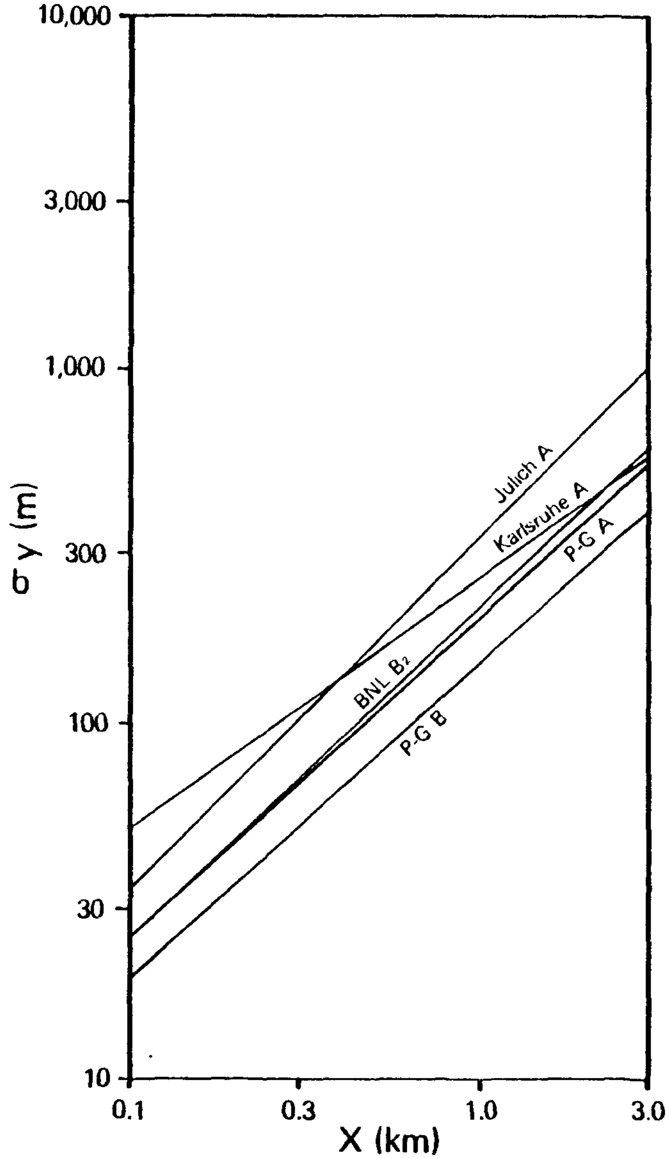

Figure 1. Horizontal dispersion coefficient (σ y) curves as a function of downwind distance (X) from the source.

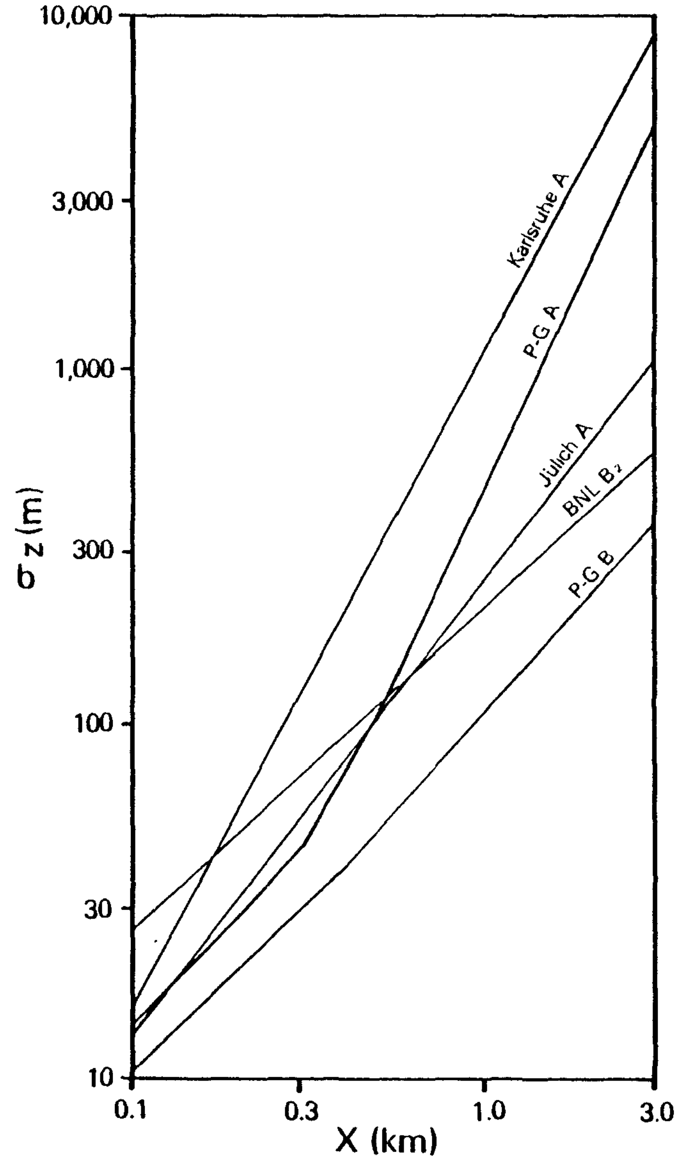

Figure 2. Vertical dispersion coefficient (σ z) curves as a function of downwind distance (X) from the source.

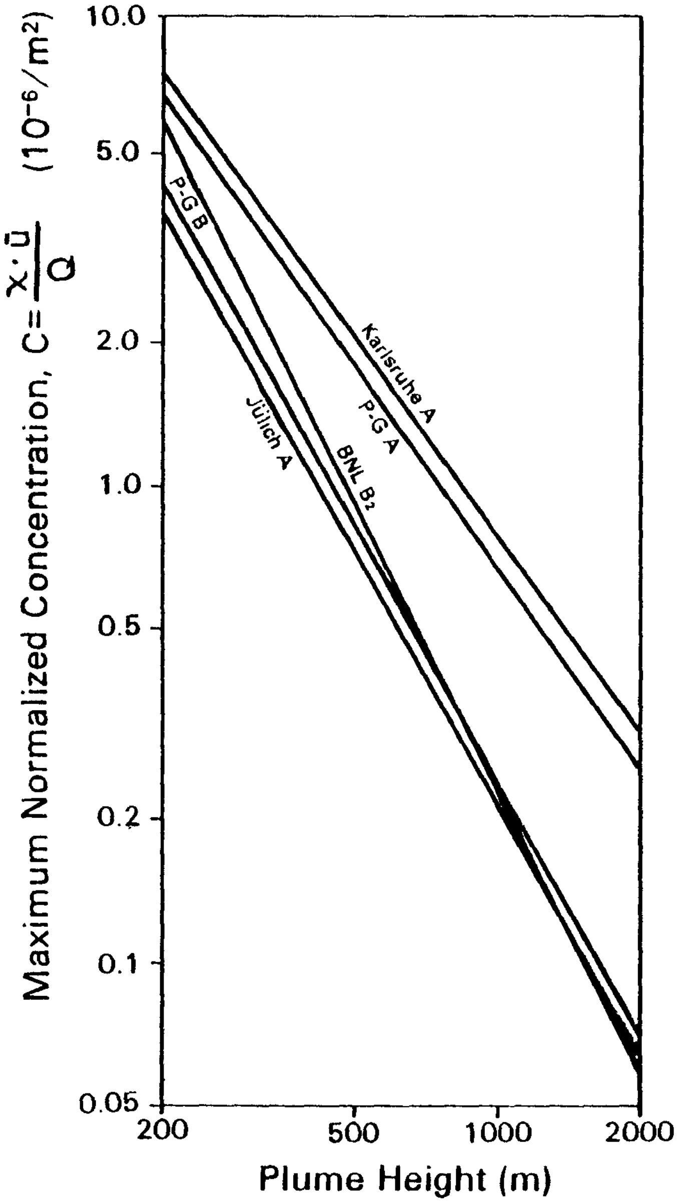

Figure 3 **Maximum normalized concentration as a function of plume height.**

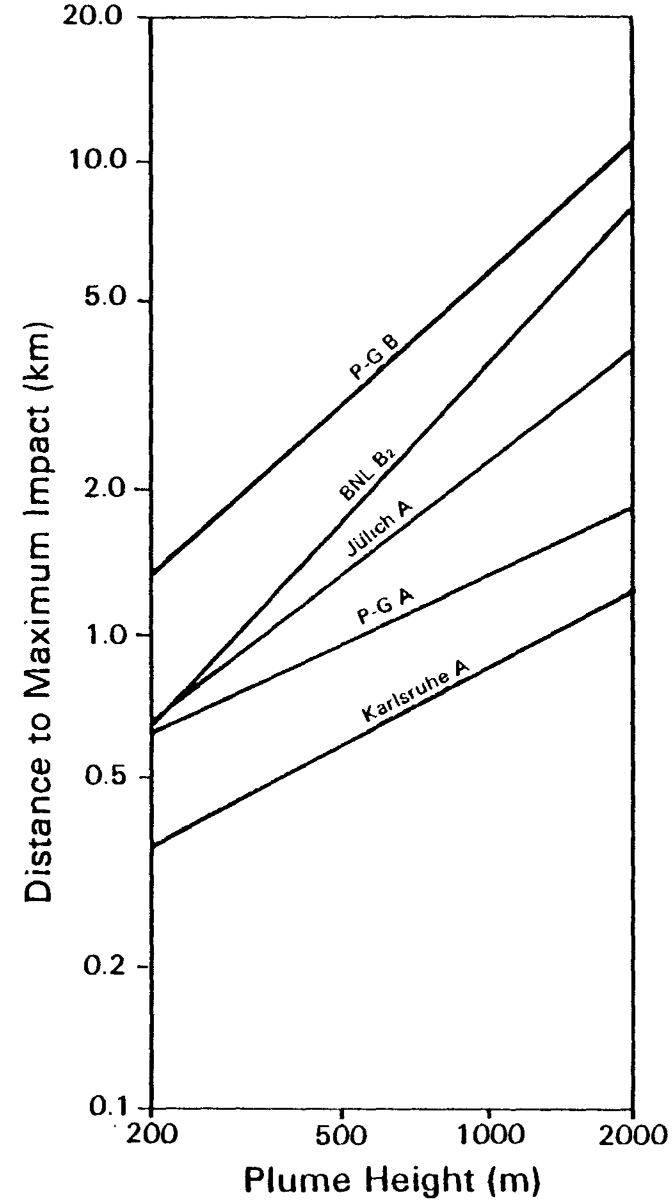

Figure 4 **Distance to maximum impact as a function of plume height.**

Figure 3 indicates the maximum normalized concentration as a function of plume height for the alternative sets of dispersion coefficient curves assuming an unlimited mixing height. Maximum concentrations would be a factor of two larger for the worst case assumption of plume trapping, where the plume height is restricted to a height equal to the height of the mixing layer (that is the plume is reflected by the base of an inversion just above the plume centerline). It can also be seen from Figure 3 that, for plume heights greater than 200 m, lower maximum normalized concentrations are calculated using the P-G B, BNL B_2, and Jülich A curves compared to the P-G A curves. The Karlsruhe A values are slightly higher (about 20% higher) than the P-G A values.

Figure 4 indicates the distance from the source to the point of maximum impact as a function of plume height for the alternative sets of dispersion coefficient curves. As can be seen from Figure 4, use of the P-G B, BNL B_2, and Jülich A curves calculate maximum impacts for plume heights greater than 200 m to occur at greater distances from the source than calculated by use of the P-G A curves. Maximum impacts are calculated to occur closer to the source by use of the Karlsruhe A curves than by use of the P-G A curves.

Analyses of the Upper Ends of the Frequency Distribution of Predictions and Observations

Sulfur Dioxide Emission Limitation (SDEL) Systems (where plant load and emission rates are reduced when high ground level impacts are predicted) are employed at both the TVA Widows Creek and Cumberland power plants.[10] Because the emission rates may be reduced at both Widows Creek and Cumberland during periods of predicted high impacts, comparison of the upper ends of the frequency distribution (based on assumed maximum emission rates) would be inappropriate. Therefore (lacking readily available hourly operations and emission data), comparisons of the upper ends of the frequency distributions can only be appropriately made for the Muskingum River and John Sevier power plants. In order to compare the upper end of the frequency distribution of predicted concentrations to maximum observed concentrations, the highest and second highest concentrations predicted to occur at the Muskingum River and John Sevier monitoring sites for each year of meteorological data available are compared in Table VII with the highest and second highest concentrations observed during each year of monitoring data available. The calculated values indicated in Table VII assume full load operating conditions as indicated in Table IV. Calculations were made using the U.S. EPA MPTER model, a steady state Gaussian model (similar to the U.S. EPA CRSTER model but able to account for multiple sources and separated stacks and locate receptors using Cartesian coordinates) using the P-G dispersion coefficients for class A stability conditions. The MPTER model was otherwise run with the same modeling assumptions used in the CRSTER model. Hourly sequential surface meterological data used in the MPTER model were from Huntington, WV, for Muskingum River and from Bristol, TN, for John Sevier; mixing height data in both cases were from Huntington, WV.

It can be seen from Table VII that maximum impacts calculated using P-G A dispersion coefficients compare well with observations. The MPTER modeling results for the Muskingum River monitors also consistently indicated that the maximum 3-hour impacts were calculated to occur at the monitor closest to the stacks.

Table VII. Highest and second highest 3-hour SO_2 concentrations observed and calculated at the closest monitor site to the Muskingum River and John Sevier power plants (ppm).

Observed			Calculated		
Year	Highest	Second	Year	Highest	Second
Muskingum River					
1978	.39	.20	1964	.43	.29
1979	.63	.41	1971	.33	.25
			1972	.40	.34
			1973	.40	.34
			1974	.36	.30
			1975	.55	.43
			1977	.41	.34
John Sevier					
1973	.17	.16	1964	.32	.32
1974	.23	.22	1970	.26	.18
1975	.45	.39	1971	.24	.21
1976	.40	.39	1972	.29	.25
1977	.43	.31	1973	.23	.16
1978	.34	.30	1974	.21	.17

Review of the meteorological conditions for the periods of predicted maximum impacts indicates that very unstable atmospheric conditions are associated with the maximum calculated values. These conditions include light and variable wind velocities, clear skies, and mixing depths of 1000 m or more which compare well with the meteorological conditions associated with the maximum observed impacts.

The model calculation methodology used in deriving the concentration estimates shown in Table VII assumes that if the calculated height of the plume at final rise by methodology of Briggs[7] exceeds the height of the mixing layer that the plume will be completely and permanently contained in the stable layer aloft and therefore that no ground level impacts will result. This modeling methodology assumes that plume rise will not be influenced by the height of the mixed layer or by the temperature structure of the atmosphere under unstable conditions as classified by Turner.[11] It might be suggested, therefore, that these modeling assumptions are not realistic and that if high concentrations are observed close to tall stacks that such concentrations result due to the plume being trapped within a mixing layer having a height much less than the height to which the plume would rise if an unlimited mixing layer existed. Such a condition would cause higher concentrations to be calculated with each of the sets of dispersion coefficients than if an unlimited mixing height was assumed. That is, the calculated maximum concentration would be greater and occur closer to the plant for lower plume heights, see Figures 3 and 4.

Analyses of the Muskingum River data assuming the effluent plume is trapped within the mixing layer observed during the period of maximum measured impact, demonstrate that use of the P-G B, BNL B_2, and Jülich A dispersion coefficient curves result in underpredictions, as well as the predicted location of maximum impact to occur further downwind from the source than that observed. Further analyses of the Muskingum River data demonstrate that if the effluent plume is actually trapped within a mixing layer sufficiently shallow such that a higher concentration is calculated to occur at the Center Bend monitor than at the next closest monitor, that use of the P-G B or BNL B_2 curves would result in a higher calculated maximum concentration than the use of P-G A curves with the plume trapped within the actual observed mixing layer.[12]

Without actual observations of plume height, wind and temperature profiles, trajectory of the elevated plume, and the three dimensional distribution of the pollutant mass with time, caution is warranted with respect to revision of the plume rise, transport and dispersion, and mixing layer trapping assumptions and associated model algorithms.

Summary and Recommendations

Based on existing measurements of maximum 3-hour impacts of tall stack effluents, it is observed that:

- The highest measured 3-hour impacts occur at the monitor closest to stacks (for cases where the directions and elevations of the different monitors relative to the source are comparable).
- Maximum impacts measured at monitors within 2 km of sources with tall stacks occur in the afternoon with light and variable wind velocities, mixing depths of 800 m or more, and very unstable atmospheric conditions.
- Highest impacts measured at monitors located more distant from the source tend to occur during conditions of higher wind speeds and/or greater atmospheric stability.

Based on calculations of maximum impacts for monitoring sites in the vicinity of tall stacks, it is observed that:

- Calculations using on-site meteorological measurements and P-G B, BNL B_2, or Jülich A dispersion coefficient curves underpredict observations during the periods of maximum impact observed at monitors within 2 km of sources with tall stacks.
- Comparisons of calculations and observations for the Center Bend monitor assuming the effluent plume is trapped within the mixing layer observed during the period of maximum measured impact demonstrate that the use of the P-G B, BNL B_2, and Julich A dispersion coefficient curves result in underpredictions, as well as the predicted location of maximum impact to occur further downwind from the source than that observed.

- Comparisons between calculations assuming the effluent plume is trapped within a mixing layer sufficiently shallow such that a higher impact is calculated to occur at Center Bend than at the next closest monitor, demonstrate that use of either the P-G B or BNL B_2 curves would result in higher calculated maximum concentrations than the use of the P-G A curves with the plume trapped within the actual observed mixing layer.

- The highest and second highest concentrations observed during each year of available measurements at monitors within 2 km of sources with tall stacks compare well with the highest and second highest values calculated by the U.S. EPA MPTER model for those monitoring sites (considering each year of meteorological input data available and assuming full load operating conditions and the use of the P-G A dispersion coefficient curves for very unstable atmospheric conditions).

- Use of P-G A and Karlsruhe A curves in models such as CRSTER and MPTER result in calculated impacts that better agree with the location and magnitude of observed maxima than use of the P-G B, BNL B_2, or Jülich A curves.

What has been observed and reported herein is that the magnitudes and distances to maximum 3-hour concentrations as predicted using model algorithms and assumptions as contained in the U.S. EPA CRSTER and MPTER models compare well (perhaps fortuitously) with observations in the vicinity of tall stacks. Note, it has not been suggested, and should not be inferred, that the P-G A dispersion coefficients (or any other set of dispersion coefficients) do or do not accurately describe the distribution of pollutant mass of an elevated plume. Nor have any claims been made or inferred herein as to the accuracy of any other model algorithms or modeling assumptions.

Due to lack of on-site measurements of plume height, wind and temperature profiles, and trajectory of the elevated plume, caution is warranted. The potential effects of factors such as increased initial plume growth during plume rise, enhanced plume rise due to multiple stacks, transitional plume rise effects, changes in height of the plume centerline, and non-Gaussian conditions influencing transport and dispersion have not been applied in the calculations or comparisons made herein.

In order to better assess the location and magnitude of maximum short-term impacts of tall stack effluents under unstable atmospheric conditions, more monitors are required to be sited near such sources than has been standardly practiced to date. Measurement of plume height, wind and temperature profiles, and distribution of the effluent mass as a function of downwind distance is also recommended in order to better ascertain the transport and dispersion of tall stack effluents during unstable atmospheric conditons. Investigations including such measurements are warranted and necessary for the improvement of present modeling methodology.

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