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Urban air pollution patterns are strongly dominated by the distribution of the pollutant sources and by transport by the mean wind. Diurnal variations in atmospheric diffusion conditions over a city tend to be smaller than over rural areas; and the urban area source pattern is as a rule fairly uniform, or at least it is described in a source inventory pattern that is gross as compared with the dimensions of point source plumes. Consequently a simple formula has been proposed[1,2,3,4] to describe the area-source component of urban air pollution;

$$X = c\ Q/u \qquad (1)$$

where X is air pollution concentration, Q is area source strength, u is average wind speed, and c is a dimensionless constant. The suggested value of the constant is, c = 225, for small particle pollution or pollution from substances not strongly affected by chemical reactions or other removal effects.[4] Strong, isolated point sources of pollution must of course be taken into account separately and individually, but there are adequate, standard methods for this.

Applications of this simple formula to various air pollution problems, including comparisons with available data, have been described in the references. The applications include: average annual values of particulate and SO_x air pollution in cities[4]; annual and seasonal area patterns of particle and SO_x pollution in cities[2,3,4]; and short period (1 hour to 1 day) urban area SO_x pollution patterns[1,2,3]. The conclusions from these comparisons is that the simple formula performs better than the output of more complicated urban air pollution models. In particular, equation (1) provides a consistently higher correlation with seasonal and annual air pollution data as compared with the output of complex numerical models.

Hanna, in another paper presented at this conference, describes a development based on this simple urban pollution model to cover the case of chemical reactions. I would like to talk briefly about application to the problem of calculating the time variation of the concentration of an inert pollutant, of which urban CO pollution, mainly by motor vehicles, is perhaps the most important example. Several recent studies have considered this problem and two, the Los Angeles study by Sklarew, _et al_.[5], and the San Francisco Bay Area study by MacCracken, _et al_.[6], include hourly values of both the CO concentration predictions of complex numerical air pollution models and observed CO values, as well as a few source strength and wind details. Using this information, equation (1) can be evaluated and compared with the corresponding prediction of the complex models. This has been done for a downtown location and an extended time period for each of these cities and the result is displayed in Table 1, in the form of correlations with observed consecutive hourly concentration values as given by equation (1) and by the respective numerical CO pollution models of these studies.

Table I

Correlation between observed hourly average urban CO values and estimates based on equation (1) and on complex numerical CO pollution models.

Location	Time Period, Hours	Correlation Coefficient: Obs. vs. Eq. (1)	Correlation Coefficient: Obs. vs. Numerical Model	
Downtown Los Angeles	17	.89	.48	(1)
Downtown San Francisco	48	.74	.66	(2)

(1) Based on data from pages 84, 96, 98, 100, and 102 of reference (5). Hourly wind values were interpolated between the three 6-hourly values given in this reference.

(2) Based on data from Figs. 8B 9, 11A, and 14 of reference (6). Hourly wind values were kindly provided by Mr. K. R. Peterson.

The conclusion is that, in addition to correlating well with annual and seasonal urban pollution-area patterns, and with shorter term pollution averages and patterns down to an hour, equation (1) also successfully describes the diurnal variability of urban CO pollution.

It is natural to ask (as several people have done) "To which pollutant sources does equation (1) apply?" That is, which of all urban pollutant sources, can be lumped in with the distributed, area-source component; and which must be treated as individual, isolated, elevated point sources?

It follows from the basic area-source model[1,2] that

$$c = (2\pi)^{1/2}\, x^{1-b}\, [a(1-b)]^{-1} \qquad (2)$$

where x is the distance from a receptor point to the upwind edge of an urban pollution-source area. The constants a and b are defined by the vertical atmospheric diffusion length, $\sigma_z = ax^b$, and so[4]

$$c \simeq x / \sigma_z \quad . \qquad (3)$$

Thus the dimensionless parameter, c, is the ratio of the horizontal transport distance of the pollutants from the upwind edge of the area source region to the depth σ_z to which these pollutants have diffused after a travel distance x. This suggests the following rule-of-thumb. If the effective height of an individual source (i.e. the source height corrected for buoyancy effects) is greater than $\sigma_z(x)$, where x is the distance from this source to the upwind edge of the area source region, then the source should be considered separately. If on the other hand the effective source height is less than $\sigma_z(x)$, then with respect to the area-source calculation it can just as well be considered to behave as a source emitting near ground level, and combined with the rest of the distributed, area source component. Naturally for individual sources that are very strong, and are near the receptor point, these approximate rules should not be used. Whenever the given, isolated source is located in the same area-source inventory "box" as the receptor is, and equals all or a large fraction, say 50% or more, of the total area-source strength in that box, then the appropriate point source formula will give a more precise result.

Finally, note that for any given value of the distance x the quantity σ_z varies with atmospheric stability, as indicated in standard discussions of diffusion. Thus whether a given source must be considered as an isolated, elevated source, or as one that is effectively at ground level, will depend in part on atmospheric stability. Our experience is that c can be assigned the approximate values 50, 200, and 600 for unstable, neutral, and stable conditions respectively, the value 225 corresponding to a long-period average. The variation of the parameter c with the size of the area-source region tends to be a second-order effect.

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