MICROSCALE CARBON MONOXIDE CONCENTRATIONS AND WIND CHARACTERISTICS ON NEW YORK CITY STREETS

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An experimental and model-development program was conducted to determine the dispersal characteristics of carbon monoxide emissions from vehicles and the characteristics of wind flows in New York City street canyons. The experimental program involved the measurement of carbon monoxide concentrations and wind conditions on rooftops and at street levels along with traffic flow for several weeks at 7 sites of differing geometries. Continuous monitoring was performed at both street (north-south) and avenue (east-west) sites in Manhattan. The model-development program involved the derivation of an analytic expression to calculate carbon monoxide concentrations and an analysis involving a stepwise linear regression procedure with both wind and carbon monoxide concentration parameters.

The wind measurements and analysis resulted in the definition of several characteristics of wind fields in these street canyons. Near the surface, the winds channel or focus parallel to the street axis. This channeling is more prevalent on streets that have large building-height (H) to street-width (W) ratios. Also, the average wind direction variance is less at the locations with greater H/W ratios.

The linear stepwise regression analysis reveals that the winds near the surface of the streets, which are 800 ft (244 m) long, are much better correlated to prevailing winds (i.e., the winds measured at the Central Park Weather Station) than those on the avenues, which are only 200 ft (61 m) long. The regression analysis produced equations that accurately predict surface wind on the streets with a residual mean square value of typically 5 $(\mathrm{mph})^2$ [8 $(\mathrm{km/h})^2$].

In general, the surface winds are less than those at rooftop locations, and greater H/W ratios produce higher surface wind speeds. For example, the measurements at one surface site on an avenue surrounded by tall (400-ft or 122-m) buildings showed greater wind speeds than are seen at an avenue site with short (50-ft or 15-m) buildings. The greater H/W ratios also produce a greater correlation between rooftop and surface wind directions. Except for the site with the lowest H/W ratio (0.5), the wind angles between the surface and rooftop positions are within 90 deg of one another 72 to 97 percent of the time. They are not correlated at the site with an H/W ratio of 0.5. Occasionally at the sites with low H/W ratios, there is some evidence that a circulation or helix pattern forms in the canyons for a short time.

One-hour air bag samples were acquired at the surface and analyzed for carbon monoxide concentration to determine the characteristics of concentrations near the street traffic. A 1-way analysis of variance was performed on the air bag samples. This analysis reveals that, at the 5 percent level of significance, there is no discernible difference in the carbon monoxide concentrations measured along the block at least 40 ft (12 m) from the corners and equidistant from the curb at a height of 5 ft (1.5 m). In addition, the variance calculated between the individual air bag concentrations and the mean value of all air bags (filled simultaneously) along the block reveals greater ventilation than at midblock. Also, the concentrations measured at all corners are not necessarily equal to one another. The average difference in carbon monoxide concentration across a 15-ft (1.3-m) sidewalk is approximately 0.97 (s.e. 0.13) ppm.

The analysis of the carbon monoxide concentrations at the various sites reveals that the ratio of the concentration difference between the surface and the rooftop levels (ΔC) and the vehicular emissions (Q) increases with greater H/W ratios. Approximately 40 linear regression analyses involving ΔC as the dependent variable, and products of Q and reciprocals of the Cartesian components of wind were performed.

The model predictions of this ratio for a uniform diffusivity constant agree well with the regression parameters averaged over a wide range of meteorological conditions. The model equation is

$$\frac{\Delta C}{Q} \propto \ell n\left[4\left(\frac{H}{W}\right)^2 + 1\right] + \ell n\left[\frac{4}{9}\left(\frac{H}{W}\right)^2 + 1\right]$$

Furthermore, there is evidence that the effective diffusivity constant is related to the reciprocal of the wind speed.

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