Characterization of Industrial Crossdrafts and Their Effect on Hood Capture Efficiency

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Introduction

Standard design methods for local exhaust hood design require the selection of the necessary capture velocity and then application of empirical equations relating capture velocity with hood flow rate. The selection of capture velocity depends on hood geometry, source generation rate, and disturbances in the vicinity of the local exhaust hood. Current design techniques for vapor degreasers require a hood flow rate of $0.25 m^3 s^{-1}$ per m^2 of tank area.(1) The design method does not account quantitatively for crossdrafts, but instead recommends eliminating crossdrafts. The little published data (1) on crossdrafts (velocity through "cracks" for various pressure differentials), is insufficient for design purposes. A more detailed analysis of industrial crossdrafts is necessary.

Objectives

The objectives of this study were to quantify the magnitude, direction, and turbulence intensity of crossdrafts near vapor degreaser local exhaust hoods and to relate the measured crossdrafts with measured hood capture efficiencies.

Methods

Crossdrafts near the local exhaust hood were measured using a TSI, Inc. two-dimensional hot-wire anemometer (IFA 100) with fast response suitable for turbulence measurements. Measured values were recorded through an analog-to-digital converter on a Toshiba T-5200 computer at a rate of 20,000 Hz on each channel. Five measurements were made in each two minute interval and the measurements were repeated approximately six times per hour over approximately a 12 hour period (6 hours per day for 2 days). Results from eight industrial sites are presented here. Anemometer measurements were converted to x- and z-velocities based on the orientation of the anemometer probe at each site. For the purposes of this study, x-velocity is parallel to the hood face and z-velocity is perpendicular to the hood face. A dimensionless crossdraft parameter was developed for each sampling interval by dividing the measured x-velocity by the calculated centerline capture velocity. Centerline capture velocity was calculated using the centerline velocity estimate for a plain slot hood. (1)

$$V_c = Q / (3.7\ L\ X) \qquad (1)$$

where: Vc = centerline capture velocity; Q = measured hood flow rate; L = tank and hood length; and X = distance along the centerline from the hood to the furthest point from the hood (1/2 tank width for tanks with hoods on both sides).

Results

A summary of the measured x-velocity, z-velocity, and turbulence intensity for all sites is shown in Figures 1-3. The box plots show the median as the centerline, the 25th and 75th percentiles as the edges of the box, and the whisker lengths are equal to 1.5 times the interquartile range. Points outside this range are shown as asterisks. Details of the methods and analysis of measured capture efficiency are given elsewhere. (2)

Examining the data for all sites, the range of x-velocities observed in industrial settings was –0.31 to 0.65ms-1. The z-velocities ranged from –0.05 to 0.32ms-1 and turbulence intensity ranged from 0.4 to 81%. Figure 4 shows measured capture efficiency versus dimensionless crossdraft velocity for all sites. Figures 5 and 6 show measured capture efficiency versus dimensionless crossdraft velocity for sites 6a and 6b, respectively.

Discussion

As shown in Figures 1–3, the highest magnitude x-velocities were observed at site 2a where the highest turbulence intensities were also observed. The highest z-velocities were observed at site 9a where the lowest x-velocities were also observed. Low x-velocity and high z-velocity should have the least impact on hood capture efficiency, since z-velocity would aid in capture. Capture efficiencies measured at site 9a were all near 1.0. As described in the Methods section, several two minute velocity measurements were made in each one hour sampling interval. Measured capture efficiency, however, was measured as an hourly average. For comparison, velocity measurements shown in Figures 1–3 were converted to one hour interval averages. Figure 4 shows that as dimensionless crossdraft velocity increases, capture efficiency decreases. There is considerable scatter in the data, which is expected since hood capture efficiency depends on a number of factors, with crossdraft

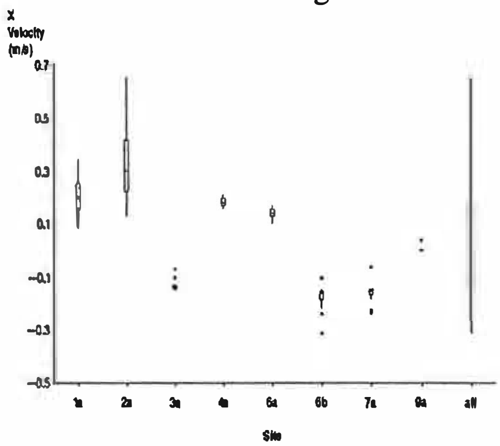

Figure 1

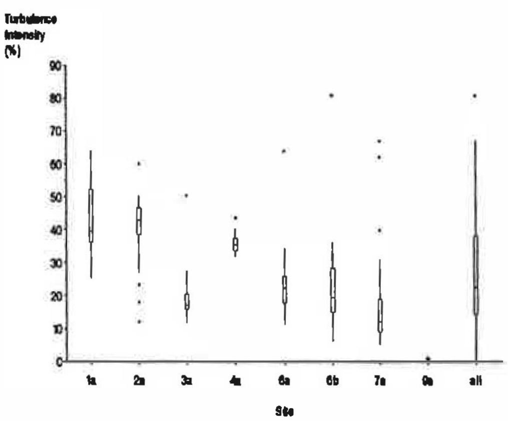

Figure 2

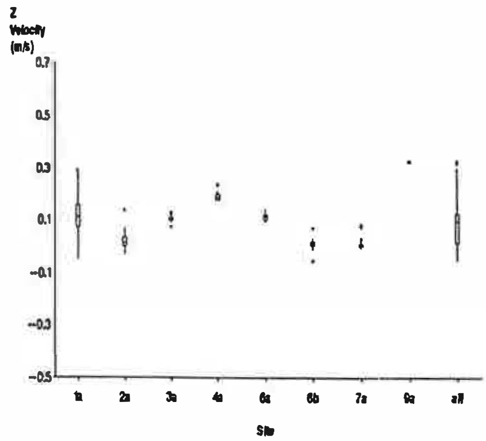

Figure 3

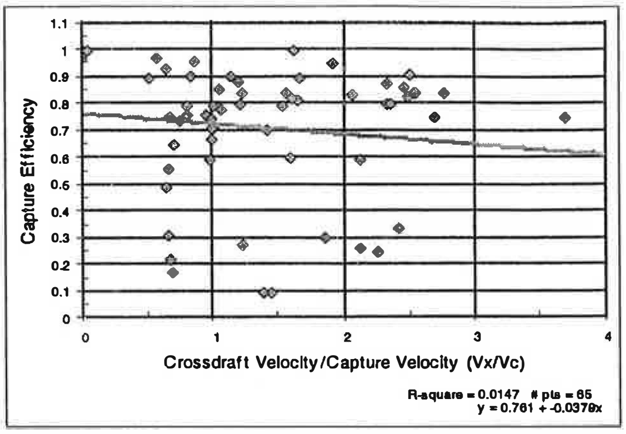

Figure 4

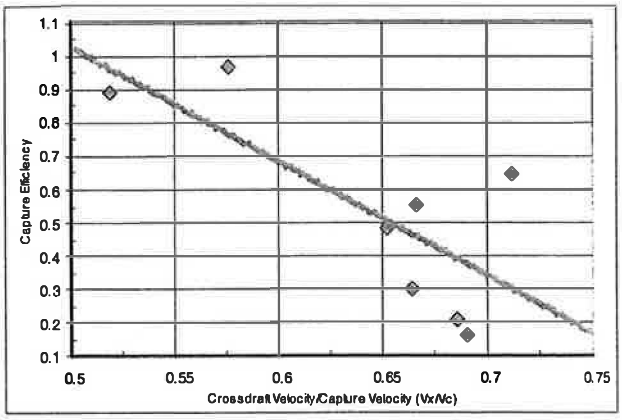

Figure 5

velocity being only one. Examination of capture efficiency versus dimensionless cross-draft velocity for each site, resulted in negative slopes at 5 of 8 sites. An example of this is shown for site 6a as Figure 5. Three sites resulted in positive slopes (sites 4a, site 6b, and site 9a). An example of this is shown for site 6b as Figure 6. Only three one-hour sampling intervals were measured at site 4a due to limited production at this facility. Very low x-velocities and higher z-velocities were observed at site 9a. There was also very little variation in velocity at this site. Degreaser activity at site 6b was very high throughout the sampling period. Degreaser activity is most likely the major reason for variation in measured capture efficiency at these sites. The results presented here show that industrial crossdrafts are often of the same or greater magnitude that the recommended capture velocities for open surface tank local exhaust hoods. Crossdrafts of this magnitude can reduce hood capture efficiency to unacceptable levels.

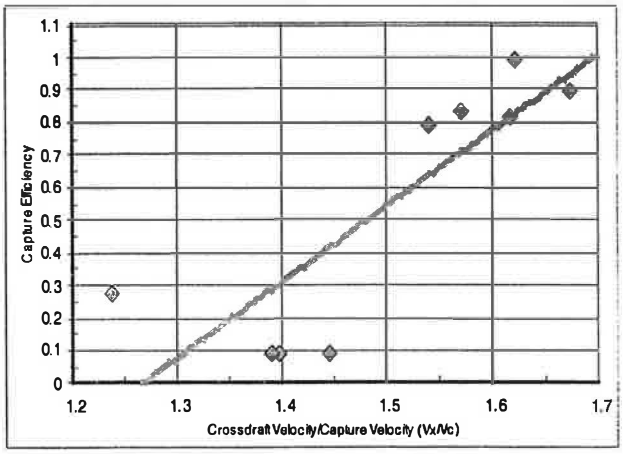

Figure 6

Acknowledgements

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