Contaminant Dispersion in the Vicinity of a Worker in a Uniform Velocity Field

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The transportation of gaseous contaminant from a low and moderate low impulse (momentum < 1 m s⁻¹) source to the breathing zone was studied in a uniform air stream flow. Results of the effects of the direction and the velocity of principal air flow, convection due to a human body, arm movement of a human being and the type of source on the concentration profiles are presented. Three important results were obtained. Firstly, for a given low and moderate impulse low impulse contaminant source in the near field of a worker, his/her orientation relative to the principal air flow direction is the most important factor in reducing occupational exposure, with an air velocity of about 0.3 m s⁻¹. Secondly, the effect of convection resulting from body heat on air flow was lower than expected. Thirdly, arm movements influence contaminant dispersion, and should be included when models assessing exposure are developed. The present data can also be used to validate existing computational fluid dynamic (CFD) models.

KEYWORDS: contaminant dispersion; exposure control; ventilation; convection of human being

INTRODUCTION

Ventilation, both general and local, is used in industry to control the emission and dispersion of air contaminants from a source to the surrounding air. In particular, it is used to reduce the exposure of workers to contaminants. The presence of the worker affects the air flow pattern strongly, and consequently contaminant transport from the source to the body. These facts are not always considered when ventilation systems are designed and evaluated.

The source characteristics — strength, geometry, initial velocity and direction of emission — may also affect the level of exposure of workers. Recent studies have indicated that both the orientation of a worker to the principal air flow direction, and the source characteristics, can have a significant effect on contaminant transportation from the source to the breathing zone. The studies of Kim and Flynn (1991), Flynn and Ljungqvist (1995) and Johnson et al. (1996) have shown that by standing in a uniform air flow, which originates behind a worker, a reverse flow wake region is created in front of the worker. At the hip level the mean direction of the reverse flow is upwards and below the hip level downwards. This upward flow, together with free convection flow, may transport contaminants from a low impulse source to the breathing zone of the worker. Studies of Carlton and Flynn (1997) showed that with a high impulse paint spraying nozzle, when the worker was oriented perpendicular to the principal air flow direction, the contaminant concentration was increased in the breathing zone. On the other hand, when nozzle momentum was low, the higher breathing zone concentrations were measured with freestream flow from behind the worker.

Studies of Ljungqvist (1979, 1987) and Ljungqvist and Reinmüller (1993, 1995) have shown that the movements of the operator, operators’ arms and hands are also of critical importance when working with fume cupboards and in weighing operations and in clean room applications.
Brohus (1997) has presented results of measurements and computer simulations in the case of a person exposed to a contaminant source in a uniform flow field. It was found that the exposure to a contaminant depends highly on the source location as well as flow direction relative to the person. The CSP (Computer Simulated Person) model was capable of simulating all the important phenomena observed close to a person.

The issues above provided the motivation for the present study, which concerns working practices that have been investigated using a human being. The objective of this study was to generate data that can be used as a basis for controlling the factors affecting the transport of gaseous contaminants from a low and moderate level impulse source to the breathing zone of a worker.

The results obtained describe the effects of the following factors on the levels of contaminant exposure: convection resulting from body heat, arm movement, variations in air velocity, body orientation, source configuration, and the presence of a work table. The present data can also be used to validate existing computational models.

**METHODS**

*Wind tunnel*

Experiments were carried out in an open circuit wind tunnel of width 1.7 m, height 2.2 m and length 3.0 m. Transparent plastic was used for the walls and ceiling. A uniform air flow field was created in the tunnel by introducing supply air from one end using two low velocity supply units (Halton LVA 351) covered with filter material. The opposite short side of the tunnel was open. Measurements were carried out at three velocities typical of working environments: 0.1, 0.3 and 0.5 m s⁻¹.

The flow conditions in the tunnel were established by measuring the free stream air velocities, turbulence intensities and temperatures at the beginning of each experiment at 280 symmetrically distributed points, using omnidirectional probes (DANTEC 54N50). At each point, the mean velocity and temperature were integrated over a period of 3 min, by taking four measurements every second. The turbulence intensity was then calculated from the air velocity measurement data. The fluctuations in velocity and temperature in the tunnel were relatively low with nominal air velocities of 0.3 and 0.5 m s⁻¹, Table 1. Large fluctuations were observed, however, with a nominal air velocity of 0.1 m s⁻¹, Table 1.

The supply air temperature and the surface temperature of both the mannequin and the human being were measured using Grafftemp-thermistor probes (accuracy ±0.3°C).

**Source**

Acetone gas was produced by bubbling air (flow rate 0.5 l. min⁻¹) through liquid acetone, using a pump (SKC), in a 30-ml glass bottle, which produced a mean acetone evaporation rate of 180 mg min⁻¹ (Fig. 1). In order to stabilise evaporation, the bottle was placed in a bucket with 2 l. of water at room temperature. Both the highly concentrated acetone flow and a dilution air flow rate of 34.5 l. min⁻¹ were directed into a 3-l. glass mixing bottle. The total source flow rate was 35 l. min⁻¹ with an acetone concentration of approximately 5000 mg m⁻³. The stability of the source flow rate was monitored in real time by an orifice plate connected to the pressure gauge, providing analogue signal output. The coefficients of variation during measurement of concentration and air flow rate were 8 and 1%, respectively. In order to check the stability of the concentration of acetone in the tracer gas, a sample (1.0 l. min⁻¹) was taken continuously from the main stream and diluted 20 times with air. The concentration was monitored continuously.

Two types of source, a line source and a point source, were used in the investigation. These were located at a height of 0.94 m and a distance of 0.35 m from the mannequin or human being. The source was located on the top surface of a table. The line source was a tube of length 0.6 m (internal diameter 17 mm) with a slit of length 0.50 m and width 8 mm. The tube was oriented perpendicular to the principal air flow direction, with the slit oriented vertically upwards. The point source was a cylinder (diameter 14 mm, height 14 mm) made from a sintered glass filter (pore size G1). Acetone gas was released from the casing and from one of the gables. The cylinder was oriented

<table>
<thead>
<tr>
<th>Nominal air velocity (m s⁻¹)</th>
<th>〈v 〉 (m s⁻¹)</th>
<th>〈Tsub0sup&gt; &lt;/sub&gt; (%)</th>
<th>〈Tsuba sup&gt; &lt;/sub&gt; (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.08 (±0.07)</td>
<td>65 (±124)</td>
<td>21 (±3)</td>
</tr>
<tr>
<td>0.3</td>
<td>0.25 (±0.05)</td>
<td>4 (±6)</td>
<td>20 (±0.5)</td>
</tr>
<tr>
<td>0.5</td>
<td>0.4 (±0.08)</td>
<td>3 (±3)</td>
<td>20 (±0.5)</td>
</tr>
</tbody>
</table>
with its axis horizontal. The location of the source is shown in Fig. 2. The initial velocities of the acetone–air mixture on the surfaces of the line and point sources were calculated to be 0.1 and 0.8 m s$^{-1}$, respectively.

**Worker and work situations**

A worker, represented by an unheated mannequin or a human being, with a height of 1.75 m and a surface area of 1.7 m$^2$, was placed in three different orientations with respect to the principal air

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**Fig. 1.** Equipment for acetone vapour generation.

**Fig. 2.** Source location and measurement point grid.
Flow direction: air flow from behind, from the front, or from the side of the worker. In the cases of back and front orientations, the worker was placed on the centre line of the tunnel at a distance of 0.66 m from the supply air wall. In the case of side orientation, the worker was located at the left wall side of the tunnel at a distance of 0.66 m from the supply air wall. Conditions in a real work place were simulated by placing a table (1.22 × 2.0 m in Series 2 and 3, and 0.6 × 0.9 m in Series 4 and 5) in front of the worker, at a height of 0.93 m. In order to investigate the effects of the worker’s movements, the person either stood still or moved his arms in a symmetrical manner, as illustrated in Fig. 3.

Measurement of concentration

The concentration of acetone was measured online by using ten photo-ionising (PID) instruments (SI-12, EAK Tallin, Estonia) and a 10.6-eV ultraviolet lamp. Nine of the sampling points were located in a vertical grid placed in front of the worker in the tunnel. The sampling grid covered a rectangular area with the top corner located at the nose of the worker, and the opposite diagonal corner close to the source, as illustrated in Fig. 2. One PID monitored the acetone concentration along the source emission line (Fig. 2). Samples from the PID instruments were transported via 3-m-long Teflon tubes (diameter 3 mm), with a sampling flow rate of 35 ml min⁻¹. The concentration data from each PID were recorded by using a personal computer with data storage rate of one measurement per second (AAC, Intab, Stenkulla, Sweden). All PID instruments were calibrated by connecting them to a gas sampling bag filled with acetone in air. This was repeated twice a day to check the stability of the instruments. The absolute concentration of acetone vapour in the tracer gas was determined by weighing the glass bottle with acetone before and after each experiment. Data concerning the source air flow rate and the elapsed time were also used in the calculations. The concentration data from the nine measuring points have been normalised using the source concentration measured at the same time. All data are therefore expressed as thousandths of the source concentration. Acetone sampling was started after the system had stabilised, which was approximately 2 min after the source flow was initiated. 1200 data points were obtained during a sampling period of 10 min. The mean values of acetone concentration from the sampling period were calculated.

Experimental design

The effects of following variables on concentration profiles were studied:

- direction of principal air flow (from behind, the side or the front of the unheated mannequin);
- velocity of principal air flow (0.1, 0.3 or 0.5 m s⁻¹);
- convection (unheated mannequin or human being);
- arm movement;
- type of source (point or line).

The following five experiments were performed.

![Fig. 3. Movement of worker’s arms.](https://academic.oup.com/annweh/article-abstract/44/3/219/165766)
1. The dependence of concentration at the grid points on the orientation of the unheated mannequin in relation to the freestream flow was studied with a freestream velocity of 0.3 m s\(^{-1}\), with a freely-hanging point source.

2. The effect of freestream velocity on concentration was studied using velocities of 0.1, 0.3 and 0.5 m s\(^{-1}\), with air flowing from behind a stationary human being, with a point source on a table.

3. The effect of body temperature on concentration was studied with an unheated mannequin and a stationary human being located in a freestream velocity field of 0.3 m s\(^{-1}\), flowing from behind the worker, with a point source on a table.

4. The effect of source type on concentration was studied with a stationary human being located in a freestream velocity field of 0.3 m s\(^{-1}\), flowing from behind the worker, with a point and line source on a table.

5. The effect of arm movement on concentration was studied with a human being located in a freestream velocity field of 0.3 m s\(^{-1}\), flowing from behind the worker, with a point or line source on a table.

Each experiment was performed at least twice.

### Statistical analysis

The results were analysed by using the general analysis of variance (ANOVA), and a comparison of the group means was performed using Duncan’s multiple range test (SAS System for Windows 6.12, SAS Institute Inc, Cary, NC, USA).

### RESULTS

The results are shown in Tables 2–6.

#### Effect of mannequin orientation on contaminant concentration

The results clearly showed that the only case in which acetone vapour reached nose level was when the mannequin was placed with the principal air stream flowing from behind the mannequin (Table 2).

#### Effect of freestream velocity on contaminant concentration

A comparison of the mean concentration at nose level (point A1), with freestream velocities of 0.1, 0.3 and 0.5 m s\(^{-1}\) flowing from behind a human being, showed that the concentrations were lower (3.6% of source concentration) with a velocity of 0.1 m s\(^{-1}\) than with velocities of 0.3 and 0.5 m s\(^{-1}\) (Table 3). However, there were no significant differences between data in these velocity groups.

We can conclude only that the concentrations for 0.1 m s\(^{-1}\) are lower than those at 0.3 and 0.5 m s\(^{-1}\).

#### Effect of body temperature on contaminant concentration

Higher concentrations (17.4% of source concentration) were observed at the nose level (point A1) of a human being, compared with an unheated mannequin (13.7% of source concentration) (Table 4). However, the difference was not statistically significant.

#### Effect of source type on contaminant concentration

The results showed only slightly higher concentrations at nose level (point A1) with a line source (7.9% of source concentration) than with a point source (6.6% of source concentration) (Table 5).

### Table 2. Mean acetone concentration (% of source concentration) with standard deviation at nose level (point A1) with freestream velocity of 0.3 m s\(^{-1}\) flowing from behind, from the side and from in front of a stationary unheated mannequin, with a point source hanging freely.

<table>
<thead>
<tr>
<th>Freestream flow</th>
<th>A1</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>From behind</td>
<td>10.1 ± 3.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.6 ± 2.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From side</td>
<td>−0.22 ± 0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From in front</td>
<td>0.08 ± 0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Negative value due to zero drift in the instrument.

### Table 3. Acetone concentration (% of source concentration) with standard deviation (at point A1) at points A1–C3 with three freestream velocities flowing from behind a stationary human being, with a point source on a table.

<table>
<thead>
<tr>
<th>Freestream velocity (m s(^{-1}))</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>2.7 ± 2.4</td>
<td>4.9</td>
<td>3.5</td>
<td>3.9</td>
<td>7.0</td>
<td>15.5</td>
<td>20.2</td>
<td>46.2</td>
<td>274</td>
</tr>
<tr>
<td></td>
<td>4.5 ± 3.2</td>
<td>5.1</td>
<td>4.3</td>
<td>2.6</td>
<td>7.0</td>
<td>14.4</td>
<td>1.4</td>
<td>11.3</td>
<td>a–</td>
</tr>
<tr>
<td>0.3</td>
<td>30.6 ± 8.8</td>
<td>34.0</td>
<td>18.2</td>
<td>33.5</td>
<td>12.6</td>
<td>12.9</td>
<td>71.8</td>
<td>194</td>
<td>366</td>
</tr>
<tr>
<td></td>
<td>10.4 ± 2.7</td>
<td>15.4</td>
<td>6.7</td>
<td>6.9</td>
<td>13.1</td>
<td>11.8</td>
<td>15.2</td>
<td>97</td>
<td>254</td>
</tr>
<tr>
<td></td>
<td>11.1 ± 5.6</td>
<td>18.6</td>
<td>12.2</td>
<td>27.6</td>
<td>0.0</td>
<td>0.0</td>
<td>a–</td>
<td>a–</td>
<td>a–</td>
</tr>
<tr>
<td>0.5</td>
<td>18.6 ± 6.8</td>
<td>21.3</td>
<td>13.0</td>
<td>26.5</td>
<td>9.8</td>
<td>4.1</td>
<td>61.3</td>
<td>100</td>
<td>351</td>
</tr>
<tr>
<td></td>
<td>13.8 ± 5.0</td>
<td>17.7</td>
<td>11.8</td>
<td>23.3</td>
<td>13.6</td>
<td>6.6</td>
<td>*–</td>
<td>a–</td>
<td>a–</td>
</tr>
</tbody>
</table>

<sup>a</sup>Outside the calibration range (400%) of the instrument.
The acetone concentrations at nose level (point A1) were higher with arm movement than without (Table 6). However, there was no significant difference between the data in the different groups.

Table 4. Acetone concentration (% of source concentration) with standard deviation (at point A1) at points A1–C3, with a freestream velocity of 0.3 m s⁻¹ flowing from behind an unheated mannequin and a stationary human being, with a point source on a table

<table>
<thead>
<tr>
<th>Source type</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unheated mannequin</td>
<td>11.2±4.3</td>
<td>13.3</td>
<td>5.4</td>
<td>9.8</td>
<td>7.7</td>
<td>4.9</td>
<td>47.8</td>
<td>131</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>16.2±3.0</td>
<td>26.6</td>
<td>9.2</td>
<td>13.2</td>
<td>13.2</td>
<td>−0.2</td>
<td>6.4</td>
<td>18.9</td>
<td>48.7</td>
</tr>
<tr>
<td>Human being</td>
<td>30.6±8.8</td>
<td>34.0</td>
<td>18.2</td>
<td>33.5</td>
<td>12.6</td>
<td>12.9</td>
<td>71.8</td>
<td>194</td>
<td>366</td>
</tr>
<tr>
<td></td>
<td>10.4±2.7</td>
<td>15.4</td>
<td>6.7</td>
<td>6.9</td>
<td>13.1</td>
<td>11.8</td>
<td>15.2</td>
<td>97</td>
<td>254</td>
</tr>
<tr>
<td></td>
<td>11.1±5.6</td>
<td>18.6</td>
<td>12.2</td>
<td>27.6</td>
<td>0.0</td>
<td>0.0</td>
<td>a−</td>
<td>a−</td>
<td>a−</td>
</tr>
</tbody>
</table>

*Outside the calibration range (400%) of the instrument.

Table 5. Acetone concentration (% of source concentration) with standard deviation (at point A1) at points A1–C3 with a freestream velocity of 0.3 m s⁻¹ flowing from behind a stationary human being, with a point or line source on a table

<table>
<thead>
<tr>
<th>Source type</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point</td>
<td>6.8±2.1</td>
<td>5.6</td>
<td>5.1</td>
<td>14.5</td>
<td>10.5</td>
<td>7.2</td>
<td>51.5</td>
<td>72.6</td>
<td>75.2</td>
</tr>
<tr>
<td></td>
<td>6.3±3.0</td>
<td>5.4</td>
<td>4.5</td>
<td>17.8</td>
<td>17.6</td>
<td>10.5</td>
<td>55.0</td>
<td>60.9</td>
<td>182</td>
</tr>
<tr>
<td>Line</td>
<td>8.9±4.4</td>
<td>6.7</td>
<td>6.0</td>
<td>19.8</td>
<td>16.4</td>
<td>10.9</td>
<td>74.4</td>
<td>132</td>
<td>172</td>
</tr>
<tr>
<td></td>
<td>6.8±5.7</td>
<td>5.4</td>
<td>4.7</td>
<td>20.3</td>
<td>16.1</td>
<td>7.8</td>
<td>126</td>
<td>257</td>
<td>65</td>
</tr>
</tbody>
</table>

Table 6. Acetone concentration (% of source concentration) with standard deviation (at point A1) at points A1–C3 with a freestream velocity of 0.3 m s⁻¹ flowing from behind a stationary human being (SHB), and from behind a human being moving his arms (MAHB), with point and line sources

<table>
<thead>
<tr>
<th>Worker type</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point source</td>
<td>6.8±2.9</td>
<td>5.6</td>
<td>5.1</td>
<td>14.5</td>
<td>10.5</td>
<td>7.2</td>
<td>51.5</td>
<td>72.6</td>
<td>75.2</td>
</tr>
<tr>
<td></td>
<td>6.3±3.0</td>
<td>5.4</td>
<td>4.5</td>
<td>17.8</td>
<td>17.6</td>
<td>10.5</td>
<td>55.0</td>
<td>60.9</td>
<td>182</td>
</tr>
<tr>
<td>Line source</td>
<td>8.9±4.4</td>
<td>6.7</td>
<td>6.0</td>
<td>19.8</td>
<td>16.4</td>
<td>10.9</td>
<td>74.4</td>
<td>132</td>
<td>172</td>
</tr>
<tr>
<td></td>
<td>6.8±5.7</td>
<td>5.4</td>
<td>4.7</td>
<td>20.3</td>
<td>16.1</td>
<td>7.8</td>
<td>126</td>
<td>257</td>
<td>65</td>
</tr>
<tr>
<td>MAHB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point source</td>
<td>8.0±7.1</td>
<td>7.0</td>
<td>5.2</td>
<td>19.3</td>
<td>13.2</td>
<td>8.8</td>
<td>36.1</td>
<td>44.8</td>
<td>72.7</td>
</tr>
<tr>
<td></td>
<td>8.5±8.4</td>
<td>7.3</td>
<td>5.5</td>
<td>17.8</td>
<td>11.3</td>
<td>6.7</td>
<td>40.7</td>
<td>51.4</td>
<td>97.1</td>
</tr>
<tr>
<td>Line source</td>
<td>8.3±7.9</td>
<td>6.6</td>
<td>5.2</td>
<td>18.0</td>
<td>11.7</td>
<td>8.0</td>
<td>50.0</td>
<td>63.3</td>
<td>54.6</td>
</tr>
<tr>
<td></td>
<td>11.2±11.0</td>
<td>8.2</td>
<td>6.0</td>
<td>19.9</td>
<td>12.8</td>
<td>8.5</td>
<td>52.2</td>
<td>68.7</td>
<td>60.6</td>
</tr>
</tbody>
</table>

However, the difference was not statistically significant.

Effect of arm movement on contaminant concentration
The acetone concentrations at nose level (point A1) were higher with arm movement than without (Table 6). However, there was no significant difference between the data in the different groups.

DISCUSSION
When combining work practices and local ventilation arrangements, the most important factor is observed to be the orientation of the worker in relation to the directions of principal air flow and source momentum. With low and moderate low source momentum (<1 m s⁻¹) air flow from the side is recommended if the formation of a reverse air flow pattern at the front of the worker, which results in an increase in exposure, is to be avoided.

The observation of high contaminant concentrations when the worker is oriented with his back towards the principal air flow direction and when the source momentum is not too high is in agreement with data obtained by Flynn and Shelton (1990), Kim and Flynn (1991), Flynn and Dennis (1991), Flynn et al. (1996) and Kulmala et al. (1994). The increase in exposure with reverse flow was greatest with a freestream velocity of 0.3 m s⁻¹, for sources of low and moderate low momentum. However, with a sufficiently low freestream air velocity, 0.1 m s⁻¹, low concentrations at nose level were measured. The momentum of the source directed away from the body has been reported by Kim and Flynn (1992) and Carlton and Flynn (1997) to reduce the transportation of contaminant from the source back to the breathing zone, even with reverse flow formation.
The effect of convection from body heat on air flow was not as significant as expected. Convection results in upward air flow around the worker. According to Clark and Edholm (1985) the maximum air velocity at face level of a standing person was 0.3–0.5 m s$^{-1}$. This convection flow was expected to strengthen the upward reverse flow and transportation of contaminant into the breathing zone. The smoke tests performed also showed that when a table was used and when there was a gap between the body and the table, the vertical convection flow from the body heat was transported uncontaminated below the table into the breathing zone. This uncontaminated air could dilute the upward reverse flow strengthened by convection flow above the table.

With a low freestream velocity of 0.1 m s$^{-1}$ the breathing zone concentrations were lower than with higher velocities of 0.3 and 0.5 m s$^{-1}$. More experiments are needed to show if there is a maximum freestream velocity around 0.3 m s$^{-1}$, where the exposure is highest.

Arm movement has the same effect as a fan, causing variations in velocity and concentration measurements as described already in previous works. Arm movement at the source level increased concentrations slightly when a table was present. With a table, the high concentrations near the source could only be diluted in vertical-up and side directions, and not vertically-down, as in the case of a free source.

In the case of a point source, the initial velocity was significantly higher than the reverse flow velocities. With the line source, a larger proportion of the contaminant is expected to follow the reverse flow, because of the lower initial velocity and the greater emission width.

CONCLUSIONS

For a given low or moderate low impulse (velocity $< 1$ m s$^{-1}$) contaminant source in the near field of a worker, his/her orientation relative to the principal air flow direction is the most important factor in reducing occupational exposure, with an air velocity of around 0.3 m s$^{-1}$.

The effect of convection resulting from body heat on exposure was lower than expected. One reason for this could be a small air gap between the body and the table, which enables uncontaminated air below the table to rise with convection resulting from body heat and to dilute the contaminated reverse flow in the breathing zone.

Arm movements just above the source increased contaminant dispersion upward.

Contaminant concentrations in the breathing zone are increased by spreading the source in a direction perpendicular to the principal air flow, and simultaneously lowering the initial velocity.

In order to reduce contaminant concentrations into the breathing zone, when working in uniform freestream, the transmission paths up to the breathing zone should be blocked, for example by using a slot exhaust integrated into the work table between the body and the source or by diluting the breathing zone by local supply air.

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REFERENCES


