RESEARCH ARTICLE

Effects of work practices and upper body movements on the performance of a laboratory fume hood

A hood user's work practices and upper body movements can adversely affect the performance of a laboratory fume hood. To quantify the possible effects, hood performance was measured while simulating typical user activities scenarios. The tested variables were two sash opening heights, two hood clutter settings, two thermal loads, and three hand–arm–trunk motions, totaling 24 ($2 \times 2 \times 2 \times 3$) different test conditions. Hood face velocity was maintained at 0.5 m/s for all tests, using a fan speed controller. For each test condition, the hood's performance was evaluated using the ASHRAE 110-1995 tracer gas test method. Duplicate measurements were made for each condition, so that a total of 48 tests were conducted, in random order. Three-way ANOVA was performed to find significant effects of work practices and upper body movements on breathing concentrations. The degree of sash opening was the most significant factor affecting hood performance, followed by hand–arm–trunk motions and thermal load. The effect of hood clutter was not statistically significant, but the interaction effect with other factors was. The highest breathing concentration value occurred during the test with the sash fully open, arms-down posture, thermal load present, and hood clutter present. These conditions created complex airflow patterns inside the hood that resulted in leakage into the breathing zone. Although the test conditions were limited, the results of this study suggest that good work practices in combination with good hood design and adequate face velocity can significantly reduce worker exposure. Reducing sash height while working in front of a laboratory fume hood is vital to reducing potential exposure to the air contaminant generated inside the hood.

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INTRODUCTION

The characteristics of exposure patterns in laboratory settings are often very different from those in industrial applications. Industrial workers are usually exposed to fewer materials for long durations, whereas laboratory workers are usually exposed to highly variable materials and quantities for short durations. For laboratory workers, such short term exposure can account for the majority of their total exposure to the materials.

In order to reduce exposure to airborne contaminants, laboratory fume hoods are widely used in laboratory environments. A laboratory fume hood is a partial enclosure that does not completely separate a person who is working in front of the hood from the airborne contaminants that are being generated inside the hood. Some good work practices required for good fume hood performance include the following:

- not using the hood as both a working hood and a storage cabinet for chemicals or equipment;

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- keeping materials inside the hood to a minimum (i.e., the amount necessary to conduct the procedure at hand) and stored in a manner that will not interfere with airflow;
- keeping space between the equipment and the back exhaust slots, so that air can flow around the equipment to the slots;
- always confirming the hood is operational.[1]

If the hood performs well under its working conditions, it can effectively reduce worker exposure to the contaminants.

The performance of a laboratory fume hood is measured by its ability to capture, contain, and remove the airborne contaminants generated inside the hood, and is affected by many factors: the design elements of the hood itself, operating conditions, room air and environment factors, worker activities, work practices, etc. Measuring hood face velocity is widely used as a metric to regularly check a hood's operational status. It has been used in many institutions because it is simple and easy to conduct, and because it provides specific numerical values. Research facilities typically set average velocity values from 0.3 (60 fpm) to 0.6 m/s (120 fpm) as the minimum acceptable value,[2] and it appears that many use 0.5 m/s (100 fpm). However, simply keeping hood face velocity at this level does not guarantee that hood users are properly protected from potential exposure.

It is not an uncommon practice to store toxic volatile chemicals, equipment, instruments, and/or apparatuses inside the hood. One survey for general hood use at a large research university reported that 99% of the hoods had some chemicals/apparatuses inside, and 45% were being operated with sash height above the worker's shoulder.[3] Many hood users keep the hood sash open when they set up/disassemble an experimental apparatus and while they are performing other functions that require access to the inside of the hood.[4,5] This is due to both a lack of training on proper hood use and the need for quick, precise control during experiments. The hood user's upper body movements and the use of a heat source inside the hood can change the airflow pattern and the resulting air contaminant transport inside the hood, affecting the hood's performance. Therefore, it is important to understand the effects of the user's work practices in assessing the user's potential exposure level, and to aid in the controlling the exposure.

Many studies have investigated the effects of various factors on hood performance in order to better understand the intricacies of hood performance. Reducing the height of the sash opening is a very important factor in lowering breathing zone concentrations or leakages.[6–9] The presence of a mannequin in front of the tested hood increases the leakage or breathing zone concentrations.[7,9–13] The presence of hand movement and other worker activities (including pipetting, weighing, centrifuging, pouring, transfer, filtration, and extraction) causes higher leakage.[12,14–17] The presence of thermal load causes higher breathing zone concentrations.[17–21] One study[8] reported that cleaning out the tested hood (i.e., reducing hood clutter) did not significantly improve hood performance, but it was the only study done on this factor.

The results of the above studies suggest that hood users' work practices and upper body movements can greatly affect hood performance. As found in a literature review, worker activities and work practices were consistently reported as having effects on measured hood performance.[22] These factors include distance between the source and sampling point, height/area of sash opening, sash movement, mannequin/human subject posture, mannequin/human subject movement, hand movement, other activities, and thermal load. The review concluded that the presence of a mannequin/human subject in front of the hood adversely affects hood performance. Furthermore, it was noted that a hood user usually performs work activities in front of the hood; thus, evaluation of laboratory fume hood performance should be conducted with a human subject or a mannequin in front of the hood, and should address the effects of the activities performed by a hood user. However, there was no study that systematically investigated the effects of all the work practices and upper body movements on hood performance.

The specific aim of this study is to examine the effects of a hood user's work practices (degree of sash opening, thermal load, hood clutter) and upper body movements (hand–arm–trunk motions) on the performance of a laboratory fume hood with a typical hood face velocity (0.5 m/s). It will attempt to fill the gap in the available information from other studies and provide the information needed to protect workers from exposure to hazardous air contaminants in laboratory environments.

METHODS

Experimental Setup

All hood tests were conducted using a 152 cm (5 ft) conventional bypass laboratory fume hood in a ventilation laboratory. The size of the hood sash was 127 cm (50 in.) wide by 71 cm (28 in.) high at its fully open position. Average hood face velocity was set to 0.51 m/s (100 ft/min) ± 1% for all tests using a fan speed controller. Airflow velocity at the hood face was measured using a TSI thermoanemometer (TSI, St. Paul, MN, USA) on a 16 point grid for the fully open sash position, and on an 8 point grid for the half open sash position. Replacement air came through a filter wall remote from the hood. During the tests, there were no other activities, uncontrolled cross drafts, or disturbances in the laboratory.

A 175 cm (5 ft 9 in.) tall worker simulated hood operations standing upright in front of the hood with his nose positioned 7.6 cm (3 in.) outside the sash plane. Figure 1 shows the configuration of the experimental setup. Five 1L beakers and two laboratory hot plates (Corning Model PC-500, Corning, New York, USA) were placed inside the hood to simulate hood clutter. The beakers were placed directly in front of the bottom hood slot and covered about half of the whole slot length. The hot plates were placed at both sides near the ejector with the front edges of the hot plates aligned at 15.2 cm (6 in.) inside the sash plane. Both hot plates (heating capacity 1,040 W each) were turned on at maximum to simulate thermal load inside the hood.

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