

# Laboratory air quality and room ventilation rates: An update

This report extends previously published empirical testing of laboratory air quality at varying room air change per hour (ACH) rates under controlled releases of organic solvents. Additional testing was performed after modifying the ventilation controls to enable reliable operations at room ventilation rates as low as 2 ACH, and with additional solvents for some test conditions. The accumulation, peak concentration, and clearance of airborne contaminants continued to be inversely proportional to the overall room ACH rate, demonstrating that low laboratory ventilation rates require exceptionally long times to clear.

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## INTRODUCTION

Previous work<sup>1</sup> investigated the relationship between laboratory air quality and room ventilation under controlled releases of organic solvent during simulated routine bench-top work as well as small spills across the range of 6–16 room air changes per hour (ACH). The accumulation, peak concentration, and clearance of airborne contaminants were found to be inversely proportional to the overall room ACH rate and significantly influenced by the distribution pattern of supply (make-up) air. In addition, breathing zone measurements were nearly always significantly higher, earlier,

and more variable than those from the combined exhaust duct for general room and chemical fume hood exhaust across all ACH rates tested. This was not surprising since the exhaust duct represents the one location through which all room air ultimately passes, and therefore has undergone the most complete mixing and homogenization prior to sampling.

Of the ACH rates previously evaluated, the greatest relative improvements in chemical concentration and clearance time from the room, regardless of release mode, occurred between about 6 and 8 ACH, with diminishing returns for rates greater than 12 ACH. This suggested that ACH rates above 12 are generally unnecessary while those below about 8 warrant careful consideration, with even lower levels suitable only for low-hazard operations or during periods of inactive non-occupancy. A key finding was that the re-engineering of supply air diffusers to provide optimal location, number, and style is an effective means to functionally increase the efficiency of laboratory ventilation and potentially allow for designs at lower ACH rates.

This current report updates previous investigations by extending the laboratory room ACH rate down to 2, something that was not possible earlier due to limitations of the ventilation control system. In addition, the effects of vapor pressure were evaluated by using additional solvents during some of the tests. As in the original study, these tests were designed to demonstrate differences in ventilation efficiencies in a typical laboratory room layout at vary-

ing air change rates, and should not be interpreted as a study of personal exposure levels resulting from chemical usage or spills.

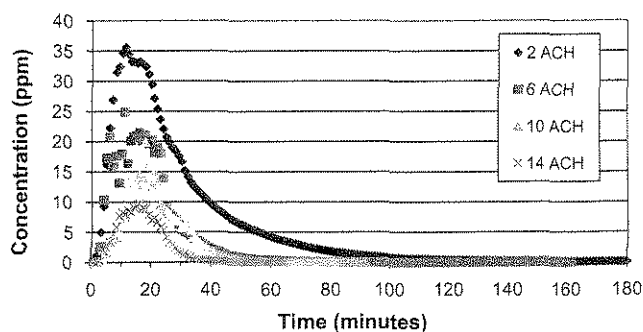
## MATERIALS AND METHODS

Laboratory indoor air quality was assessed through measurements of volatile organic compounds released under two different chemical release modes, as described previously.<sup>1</sup> Tests were performed in the same laboratory room as previous work, under non-occupied conditions with the doors closed. The room was an unoccupied modern laboratory enclosed by walls, non-opening windows, continuous suspended tile ceiling, and doors, located in a building constructed in the early 1990s specifically for biomedical research. The original building design called for airflows of 14 to 15 ACH in laboratories and their support spaces. The room contains approximately 700 ft<sup>2</sup> of floor area, with a floor-to-ceiling height of 9.5 ft. The room was operated with 100% exhaust (single pass) ventilation. Clean supply make-up air was delivered through overhead diffusers, and room air exhausted through a 5 foot wide chemical fume hood and a single overhead exhaust grill near the hallway door. Both the fume hood and the single overhead room exhaust grill were connected to the same dedicated combined room exhaust duct. As part of the original study, the number and type of supply air diffusers were modified to evaluate opportunities to improve

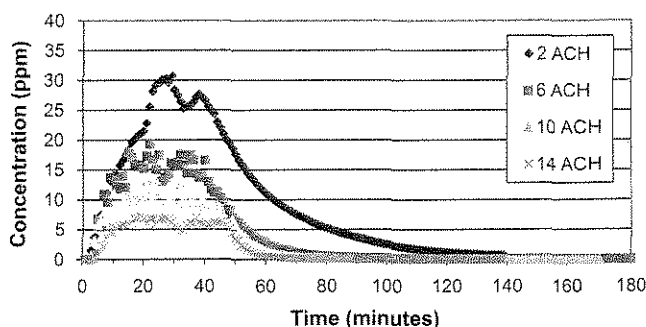
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**Figure 1.** Airborne concentrations generated from small spills (50 mL) of diethyl ether at floor level under varying ACH rates, as measured by photoionization detection from the combined room exhaust duct centerline.

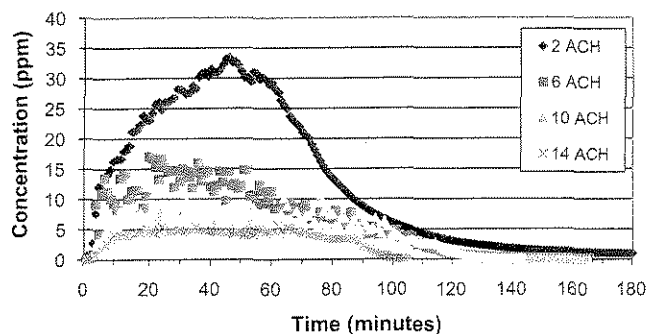


**Figure 2.** Airborne concentrations generated from small spills (50 mL) of acetone at floor level under varying ACH rates, as measured by photoionization detection from the combined room exhaust duct centerline.

mixing and contaminant clearance from room air.

Chemical concentrations were measured and datalogged at 1 minute intervals using photoionization detection (PID) instruments equipped with 10.6 eV lamps (Model ppbRAE, RAE Systems, Sunnyvale, CA). For this additional testing, measurements were only collected from the centerline of the combined room exhaust duct through which both the chemical fume hood and the single overhead general exhaust air travel. Measurements were again made under two different release modes: (1) small spills at floor level, and (2) continuous releases at bench level representing worst-case routine open air work. The bench-top work was performed exclusively with diethyl ether, while the small spills were generated with diethyl ether as well as with acetone and ethanol (95%) for comparisons across a moderate range of vapor pressures.

Tests were performed while operating the ventilation system identically as previous, but with additional runs at 2 and 4 ACH, expanding the overall test range from 2 to 14 ACH. Of the original three make-up air conditions evaluated, only the final arrangement was used during this additional testing, i.e.,

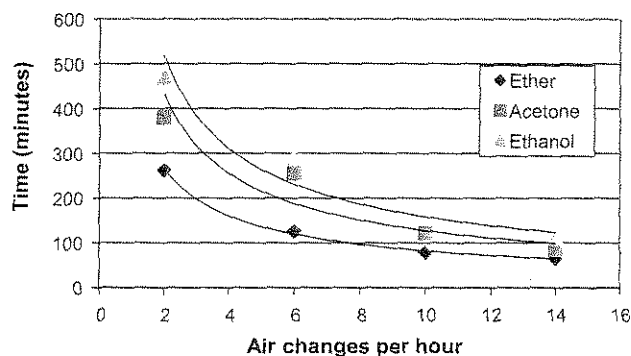


**Figure 3.** Airborne concentrations generated from small spills (50 mL) of ethanol (95%) at floor level under varying ACH rates, as measured by photoionization detection from the combined room exhaust duct centerline.

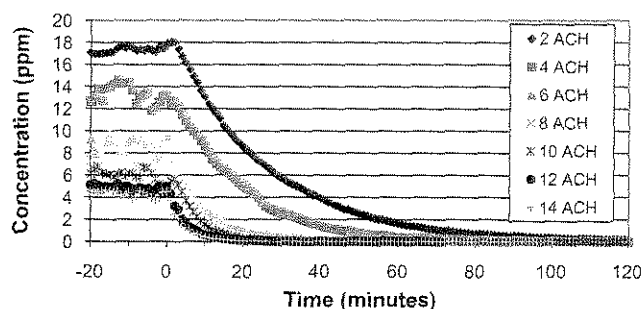
the most efficient arrangement using the three flush face radial flow style supply air diffusers. Reliable lower room ACH rates were accomplished by installing a second airflow damper in-line (manual set) in the supply air duct to provide a wider turn-down ratio than the previous existing damper alone could provide; no additional modifications were required on the exhaust side.

## RESULTS AND CONCLUSIONS

Chemical concentrations again varied predictably and significantly by ACH, mode of chemical release, and chemical, with patterns generally similar to those previously reported. As discrete events with a small limited volume of liquid, the spills showed a rapid increase in chemical concentration following spillage, a short duration peak after evaporation to dryness, and then a prolonged decay to background as chemical vapor was diluted and removed from the space (Figures 1–3). Chemical concentrations were significantly higher at lower ACH rates and decreased as ACH rates were raised. We included two additional chemicals in this testing to evaluate the effect of vapor pressure on clearance during small spills at various air change rates. Given its high vapor pressure, diethyl ether had the fastest evaporation and shortest clearance times, while spills of acetone and ethanol showed progressively slower and broader evaporation peaks, which



**Figure 4.** Clearance time to background levels after small spills (50 mL) of diethyl ether, acetone, and ethanol (95%), by ACH rate, as measured by photoionization detection from the combined room exhaust duct centerline.



**Figure 5.** Chemical concentrations generated from open bench-top releases of diethyl ether under varying ACH rates, as measured by photoionization detection from the combined room exhaust duct centerline. Containers were left open for approximately one hour to achieve stable concentrations, and then recapped to observe differences in the speed of chemical removal from room air. The graph shows the last 20 minutes of open container evaporation, recapping of all containers at "0" time, and then the first 120 minutes of subsequent clearance time. Although not shown on the graph due to scaling, clearance time to background took nearly 250 minutes at the 2 ACH rate.

became more pronounced at the lowest ACH rates (Figure 4).

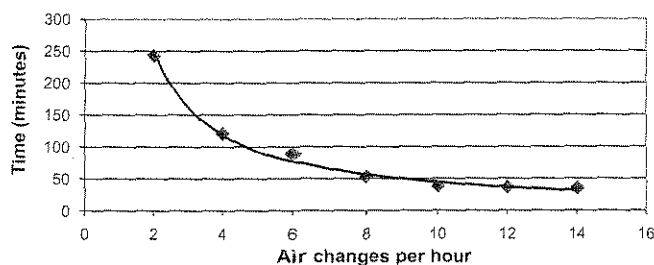
Continuous bench-top releases were again used to exaggerate open air bench-top laboratory operations that emit contaminants into room air from multiple locations. During these tests, chemical concentrations showed generally stable steady-state plateaus, followed by clearance to background levels once the containers were recapped and closed (Figure 5). The steady-state plateaus prior to recapping as well as the speed of clearance after recapping again varied predictably by ACH rate. The highest steady-state concentrations occurred at the lowest ACH rates and, like spills, clearance times under the bench-top release

mode lengthened dramatically as the ACH rate was lowered (Figure 6).

These additional tests reinforce our previous observations<sup>1</sup> by extending the

range of measurements to lower room ACH rates and other chemicals. Whether plotted by clearance time or peak concentration, measurements again showed an inverse power function with ACH. It can be concluded that compounds with even lower vapor pressures than ethanol will take proportionately longer times to clear. Since all of these tests were performed with the optimized supply air distribution pattern only, we also conclude that these results would have shown significantly longer clearance times had the original supply air conditions been used.

These results also support the recommendations of ANSI/ASHRAE<sup>2</sup> and others<sup>3,4</sup> that local exhaust ventilation is critical for source control, and effectively argue against establishing any single ACH rate for all laboratories. This is reflective of the significant differences between laboratory spaces, their mechanical systems, and their hazardous operations and materials, as well as the recognition that laboratories in real-life are used by humans and therefore dynamic and imperfect. These issues strongly support a risk-based approach to laboratory ventilation, with higher ventilation rates for more hazardous operations. While specific attention must be given to HVAC system application and layout under all ventilation rates, this work confirms earlier conclusions that levels much below about 6 ACH should only be considered for laboratories using small quantities of non- or low-hazard reagents or for inactive, non-occupied periods, regardless of the control system. In addition to creating potentially hazardous conditions for occupants, excessively low ventilation rates in most



**Figure 6.** Clearance time to background levels after open bench-top releases of diethyl ether, by ACH rate, as measured by photoionization detection from the combined room exhaust duct centerline.

regions of the U.S. will create spaces that are difficult to heat or cool without the installation of local supplemental conditioning systems.

#### ACKNOWLEDGEMENTS

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