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Hidden hero

The sustainability superpowers of building management systems

AIRAH
HVAC&R FOR A BETTER WORLD

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34 Hidden hero

Building management systems are vital for HVAC performance and efficiency, but if they're poorly designed or maintained, they can cause serious problems. Chris Stamatis, M.AIRAH, and Trevor Smith, Affil.AIRAH, showed Nick Johns-Wickberg and Mark Vender how these complex systems work in practice.

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Mitigation of individual odorous bushfire smoke semi-volatile organic compounds using multi-modal air purifiers

D. Pisaniello, M. Parker, V. Neupane, S. Gaskin, C. Ramkissoon

ABSTRACT

Exposure to bushfire smoke can have serious health outcomes. In addition, smoke infiltration into homes and buildings can result in persistent odour from smoke semi-volatiles (SVOCs). The pilot study reported here assessed the efficiency of odorous SVOC mitigation by two multi-modal air purifiers.

A bench-mounted test apparatus, contained within a fume cupboard, was constructed to assess single-pass air purifier performance. The challenge chemicals were derivatives of phenol, which are also responsible for smoke taint in the wine industry. The portable domestic air purifier (utilising HEPA, charcoal and UV) demonstrated relatively poor performance (16–52% average removal efficiency), whereas the alternative purifier (incorporating electron beam irradiation, MERV-13 and catalyst filter) achieved 90–99% efficiency. Both were effective (>98% efficiency) with respect to $PM_{2.5}$.

HEPA-, UV- and charcoal-based air purifiers appear to have limited effectiveness with respect to odorous SVOCs and advanced technologies should be explored.

INTRODUCTION

Exposure to bushfire smoke has human health implications, with long-lasting smoke events resulting in excess hospital admissions and serious outcomes for those with pre-existing respiratory disease. The use of room air purifiers represents one control option for households in bushfire-prone areas or where smoke from wood heaters is common.

Smoke can infiltrate into homes and buildings leaving a long-lasting odour. Relatedly, smoke SVOCs can give rise to unpleasant taint in wine grapes and other crops (Hayasaka et al, 2010). Such compounds include cresols, syringol and guaiacol.

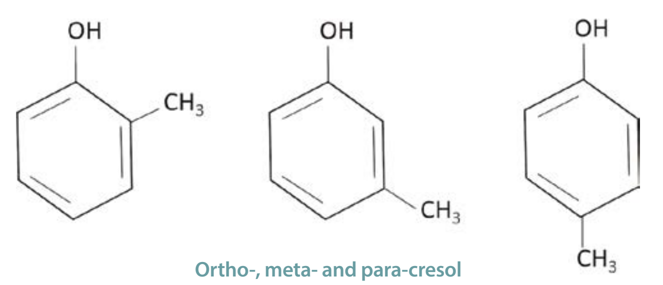
Air purifiers may incorporate multiple modes of air cleaning, such as a HEPA filter, activated charcoal, UV or cold plasma. There have been limited peer-reviewed studies of the overall performance of multi-modal systems. Wheeler et al (2023) reported on the effectiveness of an air purifier in homes in semi-rural Victoria, subject to smoke from prescribed burns. Depending on the house, the use of HEPA cleaners resulted in a reduction in indoor $PM_{2.5}$ concentrations of 30–74%.

Sorensen et al (2023) looked at the removal of volatile organic compounds (VOCs) by mobile air cleaners. For seven out of eight air cleaners examined, the clean air delivery rates (CADRs) for all VOCs tested (methanol, acetaldehyde, acetone, acetic acid, isoprene, butanone, toluene, benzaldehyde and limonene) were significantly lower than the corresponding CADRs for PM. In other words, particle capture was good, but VOC capture was poor. Indeed, re-emission of specific VOCs was observed for adsorption-based air cleaners.

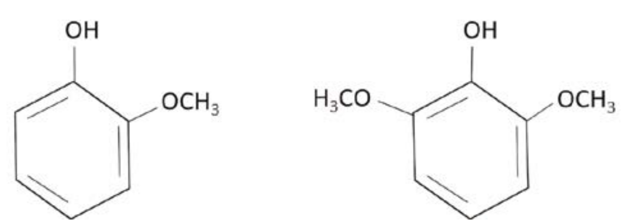
SVOCs are problematic for conventional HVAC filters as the chemicals can be airborne in two phases, namely particulate and vapour. They can move by mass transport or molecular diffusion, and there are multiple SVOCs of concern in the indoor environment (Xu and Zhang, 2011).

It appears that there have been few studies looking at air cleaner performance in terms of SVOCs, and none looking at odorous SVOCs in particular. The University of Adelaide and the Australian Wine Research Institute (AWRI) set out to conduct a pilot study to assess air purifier performance with regard to selected odorous bushfire smoke SVOCs of wine industry interest.

Figure 1: The domestic air purifier located in the test chamber.
A 10.6 eV photoionisation detector for vapours is also illustrated on the right.



Ortho-, meta- and para-cresol



Guaiacol Syringol

Figure 2. The odorous SVOCs used in the study

PILOT STUDY OBJECTIVES

The first objective was to construct a single-pass testing apparatus, sufficiently small to be enclosed in a laboratory fume cupboard to control odorous emissions from specific SVOCs introduced into the apparatus.

Secondly, the efficiency of two multi-modal air purifiers of different technologies would be assessed. Performance criteria were (a) mitigation of individual test chemical concentrations (outlet versus inlet) and (b) mitigation of $PM_{2.5}$ concentration, using diethylhexyl sebacate (DEHS) aerosol. DEHS is used to evaluate particle mitigation performance of filters, especially in the submicron size range.

TEST APPARATUS, AIR PURIFIERS AND SVOCS

The components of the apparatus included a 90L polypropylene chamber, an aerosol generator, a distribution tube, filtered make-up air, and sampling points at the air purifier inlet and outlet, as in Figure 1. The chemical structures of ortho-, meta- and para- cresol, syringol and guaiacol are shown in Figure 2. These were diluted in DEHS (approximately 1.5% w/w of each substance), to generate microgram per cubic metre (µg/m^3) concentrations. The SVOCs were freely soluble in DEHS, allowing for smooth aerosolisation of the mixture at room temperature.

Sensors included real-time pressure, particle and vapour measuring instruments. Test agent concentrations were determined by air sampling with sorbent tubes at 200 ml/min and subsequent gas chromatography-mass spectrometry (GC-MS) analysis with selective ion monitoring and deuterated internal standards. Similar porous polymer sorbent tubes and GC-MS methods have previously been used by AWRI in the analysis of the SVOCs (Hayasaka et al, 2010).

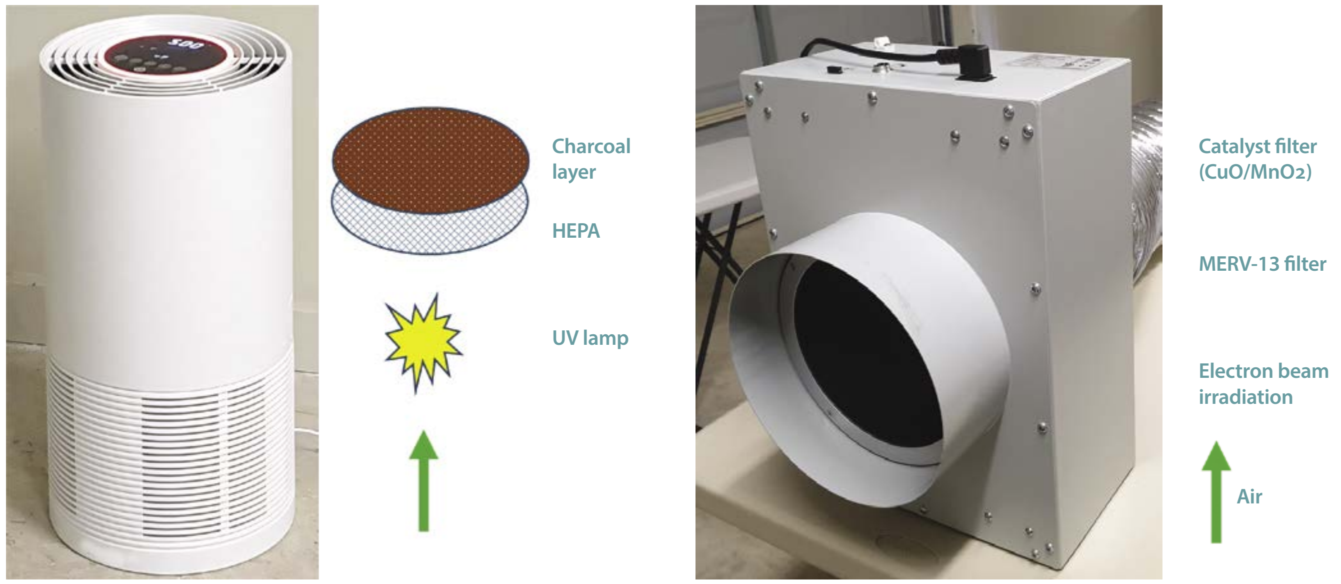


Figure 3. The multi-modal air purifiers tested: domestic air purifier (left) and HVAC-integrated air purifier (right)

Figure 3 illustrates the two air purifiers and purification elements. The domestic air purifier is a popular domestic product and features a UV lamp, a HEPA filter and charcoal filter (nominal CADR 66–337 m^3/hr). The HVAC-integrated air purifier features electron beam irradiation, MERV-13 and a catalyst filter (Pisaniello and Nitschke, 2024). The CADR is 300 m^3/hr.

RESULTS

Both air purification systems are capable of reducing $PM_{2.5}$ concentration by >98%; also PM_1 in separate experimentation (Pisaniello and Nitschke, 2024). Even with a brand-new domestic air purifier, new filters and the low air speed setting, the efficiency for removal of SVOC test agents was 16–52%, with noticeable smell at the outlet.

On the other hand, the HVAC-integrated air purifier was able to achieve 90–>99% efficiency in a single pass.

Table 1 demonstrates the average removal efficiency for the individual SVOCs.

Activating the UV lamp in the domestic air purifier did not have a measurable impact on performance.

INTERPRETATION

The high $PM_{2.5}$ removal efficiencies can be attributed to the HEPA filter in the case of the domestic air purifier and the aggregation of submicron particles in the HVAC-integrated air purifier system. The SVOC removal efficiencies of the domestic air purifier roughly follow the expected particle/vapour ratios. For example, syringol

	Guaiacol	o-Cresol	p-Cresol	m-Cresol	Syringol
Removal efficiency – Domestic air purifier*	25% (n=5)	32% (n=7)#	26% (n=7)#	16% (n=7)#	52% (n=3)‡
Challenge concentrations (µg/m³)	25.3, 29.0, 34.5, 34.6 36.7	3.3, 7.4, 8.4, 9.7, 10.1, 13.1, 29.4	2.3, 5.4, 5.5, 6.5, 8.7, 8.8, 18.3	6.5, 6.9, 11.5, 13.3, 14.1, 23.2, 29.4,	1.4, 1.7, 4.4
Removal efficiency – HVAC-integrated air purifier	94% (n=6)	99% (n=6)	90% (n=6)	97% (n=6)	>99% (n=5)
Challenge concentrations (µg/m³)	4.2, 8.6, 14.2, 19.8, 27.1, 35.1	0.9, 2.6, 5.8, 7.6, 11.8, 18.1	1.0, 2.4, 4.1, 6.1, 8.9, 16.2	2.1, 3.4, 5.8, 8.2, 11.5, 19.3	0.1, 3.9, 4.0, 9.5, 10.9

* Low speed setting

\# Initial experimentation was done with o-, m- and p-cresol only.

‡ Two results were less than the limit of detection of 0.1µg/m^3

Table 1. Average removal efficiencies for the individual SVOCs

is the least volatile of the SVOCs examined and more likely to be in particle form. However, differing charcoal affinities due to molecular shape may also be a factor.

Overall, the findings are consistent with the results reported by Sorensen et al (2023) and earlier work by Shaughnessy et al (1994), both reporting relatively poor performance with respect to the VOCs and the air purifiers tested, including a HEPA/UV combination.

It should be noted that the test concentrations were well below the Australian Workplace Exposure Standard for cresols (all isomers) of 22,000µg/m^3 as an eight-hour time-weighted average. This study did not examine bushfire smoke per se, and SVOC mitigation by HEPA filters may be higher if the SVOCs are strongly absorbed onto involatile smoke components such as inorganic particles or high molecular weight organic substances.

CONCLUSIONS

The HVAC-integrated purifier incorporating electron beam irradiation, MERV-13 and catalyst filter is capable of effective reduction of particles and odorous SVOCs typically found in bushfire smoke. Alternatives to traditional HEPA/charcoal technology are available. In addition, air purification of a wider range of SVOCs should be explored.

CONFLICT OF INTEREST

The authors declare no conflict of interest. Mention of brands does not constitute endorsement by the authors or their affiliation institutions.

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