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Enhanced Particle Filtration in a Non-Problem Office Environment: Preliminary Results From a Double-Blind Crossover Intervention Study

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INTRODUCTION

Workers in indoor environments often complain of symptoms, such as eye and nose irritation, headache, and fatigue, which improve away from work. Exposures causing such complaints, sometimes referred to as sick building syndrome, generally have not been identified. Evidence suggests these worker symptoms are related to chemical, microbiological, physical, and psychosocial exposures not well characterized by current methods [Mendell, 1993]. Most research in this area has involved cross-sectional studies, which are limited in their abilities to show causal connections. Experimental studies have also been conducted which, by changing one factor at a time to isolate its effects, can demonstrate benefits of an environmental intervention even before the exposures or mechanisms are understood [Mendell, 1993].

This study was prompted by the evidence that particulate contaminants may be related to acute occupant symptoms and discomfort [Mendell, 1993; Leinster, 1990]. The objective was to assess, with a double-blind, double crossover intervention design, whether improved removal of small airborne particles by enhanced central filtration would reduce symptoms and discomfort.

METHODS

Methods are described in detail elsewhere [Fisk et al., 1998]. To summarize, the experimental study spaces were two separate floors, with separate (variable air volume) ventilation systems equipped with conventional air filters, within a large office building in St. Louis. Occupants had sporadic complaints about comfort, but not about symptoms. Filtration was enhanced on alternate floors weekly, for four weeks in August 1996, by replacing conventional filters (estimated 3% efficiency at 0.3 micron) with highly efficient particle filters (estimated $\geq 95\%$ efficiency at 0.3 micron) in ventilation systems. Building occupants and staff were blinded to the schedule and nature of the interventions. Study staff blinded to the intervention schedule performed all questionnaire handling and analyses.

An initial background questionnaire collected demographic and other personal information. During the four-week crossover study, questionnaires distributed on Thursday for completion either on Thursday or Friday afternoon assessed outcomes including environmental comfort, performance indicators, and symptom severity that day. The questionnaire also assessed efficacy of the blinding process. Environmental measurements (described in Fisk et al., [1998]) included temperature, humidity, carbon dioxide concentration, and ventilation rate (potentially requiring adjustment in analyses) and concentrations of airborne particles, endotoxin, ergosterol, and (1→3)-β-D-glucan (potentially affected by the intervention and not used to adjust the analyses).

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TABLE I. Results of Filtration Crossover Intervention, Adjusted for Mean Temperature

Outcomes (range)		Outcome Mean	Change (*P*-value) with enhanced filtration
Symptom severity	Eyes – dry, itching, or irritated	6.2	0.07 (0.81)
(0 = none, to 25 = very severe)	Nose- stuffy or congested	6.9	−0.29 (0.37)
	Throat- dry or irritated	5.7	−0.08 (0.80)
	Chest tightness	3.8	−0.14 (0.53)
	Headache	6.2	−0.26 (0.44)
	Fatigue or tiredness	8.7	−0.21 (0.51)
	Skin- dry, itchy, or irritated	5.3	0.25 (0.27)
Performance indicators	Mental confusion (5-item scale)	1.9	−0.08 (0.009)
(1 = not at all, to 5 = extremely)	Fatigue (5-item scale)	2.8	−0.06 (0.13)
	Less productivity	3.6	−0.07 (0.11)
Environmental comfort	Too warm	2.4	−0.09 (0.10)
(1 = not at all, to 5 = extremely)	Too stuffy	2.4	−0.16 (0.006)
	Too dry	2.1	0.09 (0.07)

Intervention effectiveness was assessed by repeated measures ANOVA analysis models. Because the outcome variables were skewed, alternative statistical models were also considered: Poisson regression, over-dispersed Poisson regression, and repeated-measures logistic regression.

RESULTS

Eighty percent (392) of eligible participants returned the initial questionnaire (72% on floor 2; 84% on floor 4). Weekly response rates averaged 63% over the four crossover weeks; usable questionnaires averaged 58%. Of respondents, 60% were female; 29% were under-40-years old; 61% were white and 26% were African–American; 25% were managers or supervisors; and 55% had never smoked. Workers on the two floors were demographically similar.

Initial symptom prevalences were average for U.S. buildings [unpublished data, US EPA BASE study]. Carbon dioxide concentrations and ventilation rates were typical for US office buildings, with ventilation rates nearly constant. Microbiological parameters measured were very low. Temperature and relative humidity were mostly within ASHRAE comfort limits (22.8°C–26.1°C). Enhanced filtration reduced concentration of the smallest particles measured, 0.3–0.5 micron, by about 95%, reduced 1 to 2 micron particles by about 50%, and reduced particles larger than 2 microns by about 10%. Enhanced filtration did not change ventilation rate, carbon dioxide concentrations, or supply air flow, and had no effect on the endotoxin concentrations in the air. Air levels of ergosterol and (1→3)-β-D-glucan were too low to characterize.

For all outcomes, positive changes indicate adverse effects, and negative changes indicate beneficial effects (Table I). Temperature-adjusted ANOVA models for the effects of enhanced filtration on 13 outcomes showed that 10 outcomes improved slightly, although only two changes were statistically significant. With enhanced filtration, five of seven symptoms improved slightly and two worsened slightly, none statistically significantly (*P*-values = 0.27–0.81). All performance indicators (confusion scale, fatigue scale, self-assessed productivity) showed small improvement (*P*-values = 0.009, 0.13, and 0.11). Two environmental dissatisfaction variables, excess warmth and stuffiness, improved slightly (*P*-values = 0.10, 0.006) but dryness worsened slightly (*P*-value = 0.07). Increasing temperature, even within the comfort range, was strongly related to increases in most of the adverse outcomes, e.g., headache severity increased 1.7 units with each 1°C increase. Relative humidity was omitted from models because it was highly correlated with temperature. Results from alternative analysis models were similar to ANOVA results. Analyses showed that respondents were not aware of the specific times or nature of the intervention.

DISCUSSION

Although chance effects could be excluded only for the confusion scale and environmental stuffiness, enhanced particle filtration in this building was associated with small improvements in 10 of the 13 worker outcome measures. Findings of only slight beneficial effects from removing small airborne particles in this building may not apply to

buildings with higher symptom levels, lower ventilation rates, or significant microbiologic contamination.

Temperatures, not experimentally manipulated, were generally within the comfort range; however, the positive relation seen between temperatures and most of the adverse outcomes suggests substantial occupant benefits from lower temperatures even within the accepted comfort range.

Study strengths included the double-blind, crossover intervention design and analyses of changes within subjects. Although uncontrolled factors varying over time may have biased findings, among measured factors only temperature was related to outcomes, and adjustment for temperature was made in the analyses. Participants were not randomly allocated to experimental groups, but the crossover design reduced the potential resulting bias. If effects of enhanced filtration began after or lasted more than a week, findings could have been distorted. Health outcomes potentially related to particles other than acute symptoms were not assessed. Studying a building without excess symptoms or contaminants reduced the chance of finding filtration benefits; however, small effects in such a building, if replicated, will be more generalizable than results in a heavily contaminated building. Similar blinded, controlled, crossover studies can assess whether enhanced filtration or other reversible interventions produce larger benefits in buildings with suspected particulate contamination or higher symptom levels.

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REFERENCES

Fisk WJ, Faulkner D, Sullivan D, Dong M, Dabrowski C, Thomas JM Jr., Mendell MJ, Hines CJ, Ruder A, Boeniger M. 1998. The healthy building intervention study: Objectives, methods, and results of selected environmental measurements. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-41546).

Leinster P, Raw G, Thomson N, Leaman A, Whitehead C. 1990. A modular longitudinal approach to the investigation of Sick Building Syndrome. Indoor Air 90: Proceedings of the Fifth International Conference on Indoor Air Quality and Climate, Toronto, 1:287–292.

Mendell MJ. 1993. Non-specific symptoms in office workers: A review and summary of the epidemiologic literature. Indoor Air 3:227–236.