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Studying the Optimal Ventilation for Environmental Indoor Air Quality

Findings from a national research study exploring the impact of mechanical ventilation on indoor air quality

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Study Purpose

People currently spend nearly 90% of their time indoors,[1] making indoor air quality central to our health and well-being. Low-income populations are disproportionally affected by a range of illnesses and adverse health effects that can be exacerbated by poor indoor air quality. Therefore, improvements to the indoor environment can be an important mechanism for addressing health disparities among low-income populations.

The Enterprise Green Communities Criteria (the Criteria) is a national building standard designed exclusively for affordable housing that incorporates a strong emphasis on health-related factors. Among other health-promoting components, the Criteria requires substantial housing rehabilitation projects to comply with the industry standard for mechanical ventilation (e.g., bathroom or kitchen exhaust ventilation). The industry standard for ventilation — ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard 62.2, *Ventilation and Acceptable Indoor Air Quality in Residential Buildings* — can be challenging and costly to implement, especially when rehabilitating existing affordable housing properties.[2]

> *During the past decade, researchers have investigated the benefits of green building practices on human health; however, few studies have evaluated the effect of mechanical ventilation on indoor air quality in affordable housing.*

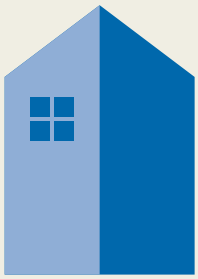
The results of such a study could provide evidence to prompt changes to construction and rehabilitation financing policies and promote broader adoption of ASHRAE Standard 62.2, ultimately leading to better health for residents. Therefore, Enterprise Community Partners joined with the National Center for Healthy Housing, The JPB Foundation, University of Illinois Chicago School of Public Health, and Icahn School of Medicine at Mount Sinai in New York City to conduct a multisite, longitudinal study to determine the effects of mechanical ventilation on indoor air quality and, by extension, on the health of residents of affordable housing.

Study Overview

The Studying the Optimal Ventilation for Environmental Indoor Air Quality (STOVE) study examined whether mechanical ventilation was effective in reducing levels of five common indoor air pollutants: nitrogen dioxide (NO_2), particulate matter 2.5 micrometers or less in diameter ($PM_{2.5}$), carbon dioxide (CO_2), carbon monoxide (CO), and formaldehyde. The study was conducted in 152 affordable homes in multifamily properties across Chicago and New York City, with data collection occurring between 2018 and 2020.

Study Group

- Housing rehabilitated using green building practices
- Ventilation that **complies** with ASHRAE Standard 62.2



Comparison Group

- Housing rehabilitated using green building practices
- Ventilation that **does not comply** with ASHRAE Standard 62.2

Study Findings

The STOVE study demonstrated that continuous mechanical ventilation complying with ASHRAE Standard 62.2 can reduce levels of common indoor air contaminants found in homes. Most noteworthy of the study's findings is the 20% improvement in $PM_{2.5}$ because of the significant public health implications of exposure to high levels of $PM_{2.5}$, especially in individuals who have asthma or other existing health issues.

Although no residential standards exist for indoor air contaminants, any reduction in the levels of these contaminants is expected to have a positive impact on human health. The table below highlights the improvement seen for the contaminants; see the final research report for additional information.[3]

The study's findings support the use of green building standards — in particular compliance with ASHRAE Standard 62.2 — during rehabilitation of affordable housing to improve indoor air quality and the health of residents. Ultimately, financing policy changes that address the complexity and cost of improving ventilation are needed to achieve broader adoption of green building practices that include mechanical ventilation. Specifically, the study's final report provides the following recommendations.

Findings in Brief

Contaminant	Health Effect of Improved Contaminant Levels	Study Group Level	Comparison Group Level	Measured Difference*	Guidance Level
		Geometric Mean			
Nitrogen dioxide (ppb)	Improved respiratory and cardiovascular health	25.6	25.3	**No significant change observed**	21[a]
Particulate matter ($PM_{2.5}$) (µg/m³)	Improved respiratory and cardiovascular health and decreased levels of mortality	13.3	17.7	**20% improvement**	12 (annual), 35 (daily)[b]
Carbon dioxide (ppm)	Improvement in cognition and reasoning	715	823	**13% improvement**	1,000[c]
Carbon monoxide (15-minute maximum) (ppm)	Reduced risk of cardiovascular impairment	2.3	2.8	**25% improvement (with continuous kitchen exhaust)**	87[d]
Formaldehyde (ppb)	Reduced risk of cancer	15.7	17.8	**44% improvement (with continuous kitchen exhaust)**	7–80[e]

Key: µg/m³ = micrograms of dust per cubic meter of air; $PM_{2.5}$ = particulate matter 2.5 micrometers or less in diameter; ppb = parts per billion; ppm = parts per million

* difference after controlling for confounding variables

[a] *WHO Guidelines for Indoor Air Pollutants*. World Health Organization. 2010. Accessed September 23, 2021. https://www.euro.who.int/_data/assets/pdf_file/0009/128169/e94535.pdf

[b] The U.S. Environmental Protection Agency (EPA) has a 12 µg/m³ annual outdoor limit and a 35 µg/m³ daily outdoor limit for $PM_{2.5}$. EPA National Ambient Air Quality Standards. U.S. Environmental Protection Agency. Updated February 10, 2021. Accessed September 23, 2021. https://www.epa.gov/criteria-air-pollutants/naaqs-table

[c] *Residential Indoor Air Quality Guidelines: Carbon Dioxide.* Health Canada. 2021. Accessed September 27, 2021. https://www.canada.ca/en/health-canada/services/publications/healthy-living/residential-indoor-air-quality-guidelines-carbon-dioxide.html

[d] California Office of Environmental Health Hazard Assessment (7 ppb) and WHO (80 ppb). *OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary.* California Office of Environmental Health Hazard Assessment. November 4, 2019. Accessed September 23, 2021. https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary. WHO Guidelines for Indoor Air Pollutants (*Op. cit.*).

[e] *Ibid.*

Study Recommendations

Systems Interventions

- Incorporate ASHRAE Standard 62.2 for both moderate and substantial rehabilitation in all green building standards, certification programs, local building codes, and subsidy and tax credit requirements.
- Ensure housing rehabilitation financing programs include the cost of installing mechanical ventilation as a portion of housing improvement budgets.
- Simplify ASHRAE Standard 62.2 so that affordable housing owners, developers, and engineers are able to understand and achieve compliance.
- Establish residential standards for indoor air contaminants.

Building Interventions

- Eliminate or reduce indoor contaminant sources and replace gas stoves with electric.
- Adopt smoke-free housing policies.
- Install mechanical ventilation systems and improve maintenance of existing ones.

Education

- Educate occupants about the importance of ventilation and about how to operate existing ventilation systems.
- Provide technical assistance to building owners, property managers, developers, and financing institutions to expand adoption of ASHRAE Standard 62.2.
- Invest in public education about the benefits of healthy indoor air quality.

The STOVE study results mark a significant contribution to the existing evidence base, demonstrating that improved mechanical ventilation in affordable homes rehabilitated using green building practices improves indoor air quality and benefits resident health.

To learn more, see the National Center for Healthy Housing's final study report and connect with Enterprise's Green Communities team.

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[1] Klepeis N, Nelson W, Ott W, et al. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *J Expo Sci Environ Epidemiol.* 2001;11(3): 231-252. doi:10.1038/sj.jea.7500165

[2] Eilers L, De Scisciolo S. *Overcoming Challenges in Housing-Based Research: Insights from a Longitudinal Study*. Enterprise Community Partners, The JPB Foundation, National Center for Healthy Housing; November 2020. Accessed November 8, 2021. https://www.enterprisecommunity.org/resources/overcoming-challenges-housing-based-research

[3] National Center for Healthy Housing. *Studying the Optimal Ventilation for Environmental Indoor Air Quality*. Columbia, MD: Enterprise Community Partners. April 2022. Available at https://nchh.org/resource-library/report_studying-the-optimal-ventilation-for-environmental-indoor-air-quality.pdf.