Abstract

Data were collected to characterize whole-house mechanical ventilation (WHMV) and indoor air quality (IAQ) in 55 homes in the Marine climate of Oregon and Cold-Dry climate of Colorado in the U.S. Sixteen homes were monitored for two weeks, with and without WHMV operating. Ventilation airflows; airtightness; time-resolved CO2, PM2.5 and radon; and time-integrated NO2, NOX and formaldehyde were measured. Participants provided information about IAQ-impacting activities, perceptions and ventilation use. All homes had operational cooktop ventilation and bathroom exhaust. Thirty homes had equipment that could meet the ASHRAE 62.2-2010 standard with continuous or controlled runtime and 34 had some WHMV operating as found. Thirty-five of 46 participants with WHMV reported they did not know how to operate it, and only half of the systems were properly labeled. Two-week homes had lower formaldehyde, radon, CO2, and NO (NOX-NO2) when operated with WHMV; and also had faster PM2.5 decays following indoor emission events. Overall IAQ satisfaction was similar in Oregon and Colorado, but more Colorado participants (19 vs 3%) felt their IAQ could be improved and more reported dryness as a problem (58 vs. 14%). The collected data indicate that there are benefits of operating WHMV, even when continuous use may not be needed because outdoor pollutant concentrations are low and indoor sources do not present substantial challenges.

Funding and Contributions

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The study was conceptualized and designed by Lawrence Berkeley National Laboratory. The LBNL team also designed methodology and provided detailed protocols for home recruitment, participant interactions and data collection. The protocols were reviewed and approved by the Central Institutional Review Board of the U.S. Department of Energy. Home recruitment, field investigation and data collection was led and managed by the research team from Pacific Northwest National Laboratory. The PNNL team led the in-home measurement and cross-calibrations in Oregon, in collaboration with Cadmus. In-home measurements in Colorado were conducted by Norton Energy Research and Development. In collaboration with the PNNL team, the LBNL team led the quality assurance and quality checks for the field collected data and compiled into an indexed dataset. LBNL team also analyzed the passive samplers from the field, calculated the minute -by-minute air exchange rates for each home and recruited the rated airflow from HVI and AHAM certificate categories.

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Data Collection Methods

Overview of the data collection

The study characterized installed mechanical ventilation equipment and monitored bath and kitchen exhaust fan use and air quality parameters inside and outside of homes. Research teams characterized the building structure and mechanical equipment; conducted diagnostic measurements of envelope and duct air tightness and ventilation airflows; and deployed samplers, sensors and other devices to track equipment use and measure IAQ parameters. Participants provided information about the household, their assessment of air quality in the home, household activities that can impact ventilation and IAQ, and what they knew about their WHMV system. Measurements were made over week-long periods with most homes monitored for one week and a subset of 16 monitored for two weeks, one with and one without WHMV operating, resulting in 71 measured weeks in a total of 55 homes.

Field teams visited one-week homes twice, with a mid-week check-in call. Two-week homes had a third visit between the weeks for changing of passive samplers and filters for PM2.5 sampling. The study was implemented by two teams, one in each area, using common protocols. If a WHMV system was found to be inoperable or operating with airflow rates that did not meet 62.2-2010, the field team assessed if it could be adjusted to be compliant; and adjustments were made for participants who agreed to have their homes measured as part of the WHMV group.

Protocols covering recruitment, participant interactions and data collection were reviewed and approved by the Central Institutional Review Board of the U.S. Department of Energy.

Eligibility and recruitment

The study was limited to owner-occupied single-family homes built in 2013 or later that did not allow smoking inside. Additionally, since the focus was on the impact of mechanical ventilation, participants were required to agree to not substantially use natural ventilation (i.e., to not leave windows and doors open for extended periods) and to not change the WHMV setting (on or off) prescribed for the monitoring period.

Data were collected in marine and cold-dry climates in the US states of Oregon (OR) and Colorado (CO). Building codes in both locations require bathroom exhaust and WHMV in new construction, with the airflows specified in the IRC. Kitchen exhaust has been required in Oregon since 2008. The Colorado code, which followed the IRC, allowed recirculating range hoods. Recruitment was designed to include homes built to local codes and also above-code homes certified to meet higher standards, including Earth Advantage in Oregon and DOE Zero Energy Ready Homes in Colorado.

Usage notes

Whats in the dataset?

The dataset contains the most relevant information collected about the houses and their mechanical equipment, results of the participant survey, results of air leakage and airflow measurements at the homes, pollutant concentrations measured by time-integrated passive samplers inside and outside of the home, usage of cooktop and oven, external door and window open state, and time-series or air pollutants and environmental indicators measured within and outside of the apartments

Organization of Dataset

Airflow

This folder contains time-resolved data of the calculated overall air exchange rate. The total air change rate for the home depends on a combination of the various mechanical ventilation systems with the natural infiltration due to stack and wind effects and the envelope leakage. The natural infiltration rate was estimated using the single zone models described in the ASHRAE Fundamentals Handbook assuming no substantial window or door opening. The total air change rate was calculated for each minute by combining the airflows from mechanical ventilation fans, duct leakage and natural infiltration using procedures from the ASHRAE Handbook of Fundamentals. There is one csv file for each measured week. See BAIAQ\_PNNL\_Airflow\_ReadMe for more details.

DeltaQ

This folder contains data about the DeltaQ test results for each home. The results contain the supply and return duct leakage of the HVAC system for each home. The measured values were carefully reviewed by a researcher and error values were excluded and adjusted. The results also include the total envelope leakage (ACH50) for each home. There is one EXCEL file containing the data for all homes.

Home\_characteristics

This folder contains data about the house, including basic characteristics, air leakage test results, and measured airflow rates of mechanical ventilation equipment. There is one EXCEL file containing the data for all homes. The home characteristics form used by the field team is also included in the folder to explain the data parameters used in the EXCEL file.

IAQ\_Activity\_Monitoring

This folder contains time-resolved indoor and outdoor air quality data, including PM2.5 as measured by MetOne photometry (PM), indoor PM concentrations measured by low-cost sensor (PM1, PM25, PM10), carbon dioxide (CO2), formaldehyde (FRM), temperature (T), and relative humidity (RH) in different rooms. Data also included T and RH measured at the supply air register (AS).

This folder also contains time series data of cooktop burners and oven monitored using iButton temperature sensors, other cooking devices monitored using AC power logger, whole house mechanical ventilation system, kitchen range hood and bathroom fan on/off monitored using either an anemometer or a motor sensor, and open/close status of doors and windows monitored with state sensors. There is one csv file of 1-minute time-series data for each home, totaling 71 csv files.

See IAQ\_Activity\_Monitoring\_ReadMe for data header definitions and data issues.

Most instruments had internal logging and special software to download data from the field instruments and convert the data files to csv format. One-minute resolution time-series data files were created for each house using a python script that pulled data from multiple csv files, aligned data by time, executed unit conversions, and interpolate data that were measured at different time resolutions. Visual review was conducted on the compiled files to check for translation or writing errors, indications of instrument malfunction, mislabeled units or unit conversion errors, mislabeled location, and time stamp errors. More detailed information about data processing and QAQC are described in the paper.

IAQ\_Sample

This folder contains the results of time-integrated air quality samples, including passive measurements of formaldehyde, nitrogen dioxide and nitrogen oxides, and PM2.5 gravimetric filter measurements. There is one EXCEL file containing all data. Detailed information about chemical analysis of air samples are provided elsewhere in the journal paper.

Occupant\_Activity

This folder contains tabulated information provided by study participants from their daily activity logs. There is one EXCEL file containing all the daily occupancy data transcribed by a researcher. There are 55 EXCEL files containing daily activity logs for each home, named by home\_ID and measured days. The MS Word file shows the format of the daily activity log used.

Occupant\_Survey

This folder contains survey results about the occupants, their general activities related to ventilation and IAQ satisfaction, completed by study participants. There is one EXCEL file containing data transcribed by a researcher. Two homes did not complete surveys, as indicated by "No survey" in the response. The MS Word file contains questions of the occupant surveys.

WHMV

This folder contains three excel files:

WHMV configuration summarizes the whole house mechanical ventilation system characters for each home, including system type, airflow and runtime as found and during the test week, WHMV labels condition, household survey answers for WHMV recognition and HVAC filter information.

BA\_fan\_airflow&sound\_rating contains the airflow and sound level rated by Home Ventilating Institute and Association of Home Appliance for all bathroom and laundry fans installed in each home

Rangehood\_airflow&sound\_rating contains the airflow and sound level rated by Home Ventilating Institute and Association of Home Appliance for the range hood installed in each home