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Indoor air quality in new and renovated low-income apartments with mechanical ventilation and natural gas cooking in California

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Abstract

This study presents pollutant concentrations and performance data for code-required mechanical ventilation equipment in 23 low-income apartments at 4 properties constructed or renovated 2013-2017. All apartments had natural gas cooking burners. Occupants pledged to not use windows for ventilation during the study but several did. Measured airflows of range hoods and bathroom exhaust fans were lower than product specifications. Only eight apartments operationally met all ventilation code requirements. Pollutants measured over one week in each apartment included time-resolved fine particulate matter (PM_{2.5}), nitrogen dioxide (NO₂), formaldehyde and carbon dioxide (CO₂) and time-integrated formaldehyde, NO₂ and nitrogen oxides (NO_x). Compared to a [recent study](#) of California houses with

code-compliant ventilation, apartments were smaller, had fewer occupants, higher densities, and higher mechanical ventilation rates. Mean PM_{2.5}, formaldehyde, NO₂, and CO₂ were 7.7 µg/m³, 14.1 ppb, 18.8 ppb, and 741 ppm in apartments; these are 4% lower, 25% lower, 165% higher, and 18% higher compared to houses with similar cooking frequency. Four apartments had weekly PM_{2.5} above the California annual outdoor standard of 12 µg/m³ and also discrete days above the World Health Organization 24-h guideline of 25 µg/m³. Two apartments had weekly NO₂ above the California annual outdoor standard of 30 ppb.

Methods

This study evaluated IAQ in 23 low-income apartments at 4 properties with natural gas cooking burners and mechanical ventilation equipment having specifications that met state building code requirements. The inclusion criteria were for apartment units to have (1) mechanical ventilation (MV) equipment that met the requirements of California's Title 24 residential building code and (2) a natural gas cooking appliance. Required MV equipment were an exhaust fan in each bathroom, a kitchen exhaust fan or range hood, and equipment providing regular ventilation to the dwelling unit – each having specifications that met the code-minimum airflow requirements.

Each property was visited in advance of the week of monitoring to confirm the presence of compliant MV equipment; this was done by inspecting 2-4 unoccupied units per site. Recruitment commenced following this visit. During the first visit, teams provided the participant with a paper version of the survey to obtain information about satisfaction with air quality and thermal conditions in the home and routine activities that impact ventilation and IAQ. Characteristics of mechanical ventilation equipment, cooking appliances, and thermal conditioning systems were documented and unit airtightness and ventilation equipment airflows were measured. Temperature, humidity, carbon dioxide and air pollutant concentrations were measured inside each apartment and air pollutant concentrations were measured outdoors on site. Sensors were installed to monitor use of gas cooking burners, ventilation equipment, and natural ventilation. Participants were asked to record occupancy and activities during each day of monitoring. Surveys and activity logs were collected and equipment was removed after one week of monitoring in each apartment.

The study was led by Lawrence Berkeley National Laboratory (LBNL). Association for Energy Affordability recruited study buildings and completed a large portion of the field work. All study protocols involving interactions and collection of data from private individuals and monitoring in occupied homes were reviewed and approved by the LBNL Human Subjects Committee. Research Funding and technical contributions of collaborators are noted below in the acknowledgements.

Usage Notes

What is contained in this dataset?

The dataset contains the most relevant information collected about the apartments 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 of air pollutants and environmental indicators measured within and outside of the apartments

Organization of Dataset

Home_Equipment_Data

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 raw and adjusted PM2.5 as measured by DustTrak and PDR photometry (PM), ultrafine particles number concentration (UFP), PM concentrations measured by low-cost sensor (PM1, PM25, PM10), carbon dioxide (CO2), nitrogen dioxide (NO2), formaldehyde (FRM), total volatile organic compound (tVOC), temperature (T), and relative humidity (RH). Data also included T and RH measured at the supply air register (AS). Data also include hourly outdoor PM2.5 and NO2 concentration from the closest regulatory air monitoring stations (AQS).

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, 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, total 23 csv files.

See KV_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 issues identified are explained in the ReadMe file.

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 data transcribed by a researcher, which was independently spot checked by another researcher to confirm accuracy. The PDF 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.

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Data Files

Download dataset

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