Feasibility of combining airborne pollutant measurements with spatially resolved infrared thermography to develop a novel tool for indoor air quality investigations

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Keywords: indoor air quality, thermal imaging
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People in industrialized societies tend to spend up to 90% of their time indoors. Thus, residential exposures to various airborne pollutants may substantially contribute to overall exposures. Indoor air quality (IAQ) and the resultant exposures might be heavily impacted by occupant behavior as well as the properties and operation of the buildings themselves. Therefore, in indoor air quality investigations, it is important not only to quantify the presence of various pollutants but also to relate the findings to the type and operation of the buildings. Typical air quality measurements, as well as traditional building assessment strategies, are well-known and established tools. However, they are typically time and effort consuming. In this study, we investigated the feasibility of combining integrated laser scanning and thermal imaging with traditional IAQ measurements and questionnaires to develop a comprehensive and time-effective tool to determine housing-related health and safety hazards. This methodology was applied in two multi-apartment affordable housing residential buildings located in a Northeastern US urban community owned and operated by a non-profit organization.

In each building as well outdoors, viable bacterial and fungal aerosols, total fungal spores, carbon dioxide, carbon monoxide, formaldehyde, PM2.5, ultrafine airborne particles, endotoxins, allergens, air velocity at return vents, temperature and humidity were measured. Terrestrial laser scanning in conjunction with infrared thermography was used to examine potential deficiencies in building structure, insulation and moisture on surfaces. Interviews helped to understand the residents' behavior and find out their concerns about housing conditions.

The bioaerosol concentrations in the apartments were below 1,000 CFU/m^3; total fungi from 65 to ~2,500 count/m3. CO_2 and CO levels were generally less than 1,500 ppm and 1 ppm, respectively. 24-hour gravimetric measurements of PM2.5 concentrations were below 100 µg/m^3 while one hour total PM mass concentrations ranged from 11 to 687 µg/m^3. Formaldehyde results varied from non-detected to 115 ppb. Endotoxins up to 2,300,000 EU/g and mouse and cockroach allergens were detected. These data were then correlated with building defects identified in laser scan and infrared data for each apartment and entire buildings.

It was found that the amount of missing insulation as determined by infrared scans in individual apartments was correlated highly and significantly ($p<0.001$) with the total airborne particle number; the amount of missing insulation was also correlated highly and significantly ($p<0.0001$) with the presence of airborne culturable mold. Both observations were indicative of outdoor pollutant penetration indoors thus contributing to indoor exposures. The questionnaire data indicated that residents' behavior is one of the main factors contributing to IAQ variability between apartments.

Overall, the combination of traditional IAQ measurements, questionnaire data and spatially resolved infrared thermography shows a promise of being a comprehensive and time-efficient tool to investigate housing-related health and IAQ issues.

This work was supported by the US Department of Housing and Urban Development (HUD) grant "Development and Evaluation of Cost-Effective Methods and Protocols for Identification and Assessment of Housing-Related Hazards," NJHHU0019-13.