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Occupant perceptions and a health outcome in retail stores

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ABSTRACT

Indoor Environmental Quality (IEQ) in commercial buildings, such as retail stores, can affect employee satisfaction, productivity, and health. This study administered an IEQ survey to retail employees and found correlations between measured IEQ parameters and the survey responses. The survey included 611 employees in 14 retail stores located in Pennsylvania (climate zone 5A) and Texas (climate zone 2A). The survey questionnaire featured ratings of different aspects of IEQ, including thermal comfort, lighting and noise level, indoor smells, overall cleanness, and environmental quality. Simultaneously with the survey, on-site physical measurements were taken to collect data of relative humidity levels, air exchange rates, dry bulb temperatures, and contaminant concentrations. This data was analyzed using multinomial logit regression with independent variables being the measured IEQ parameters, employees' gender, and age. This study found that employee perception of stuffy smells is related to formaldehyde and PM_{10} concentrations. Furthermore, the survey also asked the employees to report an annual frequency of common colds as a health indicator. The regression analysis showed that the cold frequency statistically correlates with the measured air exchange rates, outdoor temperatures, and indoor $PM_{2.5}$ concentrations. Overall, the air exchange rate is the most influential parameter on the employee perception of the overall environmental quality and self-reported health outcome.

1. Introduction

A number of previous studies investigated Indoor Environmental Quality (IEQ) parameters and their impacts on occupant perceptions of the environment. A few studies demonstrated that poor IEQ deteriorates both human health and productivity [28,14,20,30]. However, most of the existing studies focused on office, campus, and residential buildings [10,17,7,29]. Studies involving big-box retail stores are limited [8,9,22]. It is necessary to evaluate IEQ in retail stores due to varied occupant exposure time including the short-term (customer) and long-term (employee) exposure to indoor environment [9]. The poor IEQ in retail stores may affect both customer comfort and employee productivity. An existing study found that indoor CO_2 concentrations that exceed 1000 ppm were related to occupant complaints of sick building symptoms (SBS), such as drowsiness as well as irritation of eye, nose, and respiratory tract [22]. Additionally, IEQ affects the emotions and purchase decisions of customers, as well as the thermal comfort and working efficiency of employees [5]. Therefore, the evaluation of IEQ in retail stores may benefit both customers and employees.

The present study combines on-site measurements and a survey study, aiming to quantitatively evaluate possible correlations between the overall IEQ and employee perceptions in retail stores. The survey study investigates the employee IEQ perceptions of multiple indoor environmental properties, and the on-site measurements of environmental parameters provide additional insights into survey responses based on statistical analyses.

2. In-store measurements of indoor environmental quality (IEQ)

This study focuses on data collection in retail stores, but its design draws on the experiences with the Building Assessment Survey and Evaluation (BASE) conducted for the office buildings [12,18]. The current study covers 14 retail stores from Texas and Pennsylvania in five categories defined as home improvement, general merchandise, grocery, furniture, electronics, and office supply. The site measurements of IEQ parameters were performed from May, 2011 to July, 2012. The measured parameters provided a

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physical description of indoor environment, and provided data for a statistical analysis of the survey responses. The indoor measurements included two parameter types: (1) parameters related to indoor thermal conditions including air exchange rate (AER), relative humidity (RH), and indoor dry bulb temperature; and (2) parameters related to indoor air quality including formaldehyde, particulate matter 2.5 μm ($PM_{2.5}$), particulate matter 10 μm (PM_{10}), and total volatile organic compound (TVOC). Overall, the study collected more than two dozen indoor parameters related to IEQ, thermal comfort, and contaminants in a week long time period [32,36].

The IEQ measurements used two sampling methods including (1) a fixed sampling with instruments in fixed positions, and (2) mobile sampling with portable instruments installed within baskets or shopping carts. The fixed sampling is suitable for large or heavy instruments to obtain continuous datasets, but can only represent the IEQ conditions at certain locations in retail store buildings. The mobile sampling represents the overall store conditions, but the measurements provide discrete datasets. Table 1 shows the measured indoor parameters with corresponding sampling methods. Thermal parameters of the indoor environment were measured in multiple fixed sampling locations to represent the condition of overall thermal environment. Indoor contaminants were measured by mobile sampling to represent the integrated distribution of contaminants inside the stores.

The detailed data collection processes included following parameters:

(1) CO_2 concentrations

Many previous investigations reported a relationship between indoor carbon dioxide (CO_2) concentrations and health perceived air quality. The indoor CO_2 concentration is also associated to ventilation rate [6,31]. During the measurements, a commercial monitor (Telaire 7000) collected the indoor CO_2 concentrations for ventilation rate estimations, and an assessment of air mixing in the stores. The monitors collected data at five locations in each retail store for four to five days, with the elevation of 1.1 m–2.0 m above the floor in each location. The overall average indoor CO_2 concentration in all retail stores varied from 381 ppm to 716 ppm, indicating a sufficient amount of outdoor air based on the CO_2 concentration criterion [3].

(2) Air temperatures and relative humidity

Air temperatures and RH may significantly impacts the perception of IEQ. A study demonstrated that the perceived air quality decreases with the increase in air temperature and humidity at a constant pollution level [13]. The Telaire monitors with HOBO data loggers collected the indoor RH at the same locations where CO_2 measurements took place. For retail store buildings in Pennsylvania, iButton sensors collected the data with three elevations above the floor, at 0.1 m, 1.0 m, and 1.7 m above the floor. Fig. 1 shows the average indoor air temperatures and relative humidity levels in retail store buildings within the psychrometric chart with all of the measured points being within the thermal comfort zone defined in the literature (ASHRAE, 2010). The highlighted region in Fig. 1 shows the range of operative temperatures and humidity ratios for 80% occupant acceptability. This region is based on a 10% dissatisfaction criteria for general thermal comfort.

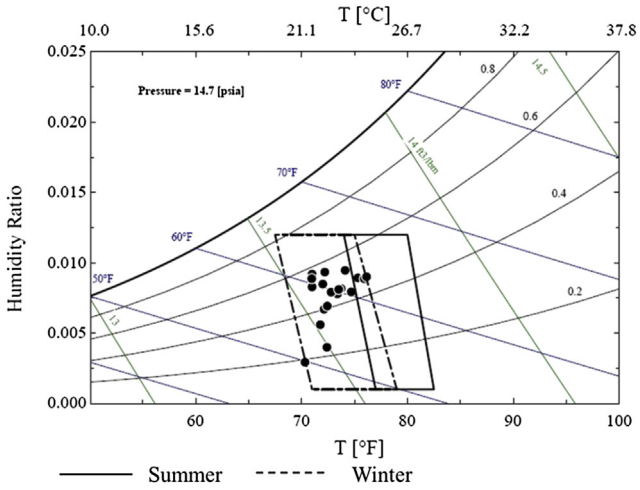

Fig. 1. Average indoor air humidity and temperatures in the psychrometric chart.

(3) Volatile organic compound measurements

The complex mixtures of volatile organic compounds (VOCs) might be the primary source of mucosal irritation, a prominent symptom typically resulting in headaches, fatigue, and dizziness [16]. In the current study, sorbent tubes, summa canisters, and photoionization detectors (PID) measured VOC. The sorbent tubes were packed with 2, 4-dinitrophenylhydrazine (DNPH) monitored formaldehyde and acetaldehyde, based on the U.S. EPA Compendium Method TO-11A. The summa canisters were used to collect the air in the retail store buildings for VOC analyses. The PID (ppbRAE plus PGM-7240, RAE Systems, Inc.) monitored the TVOC concentration with both fixed and mobile sampling methods. The TVOC concentrations ranged from 38 ppb (100 $\mu g/m^3$) to 2955 ppb (6300 $\mu g/m^3$) with an average value of 799 and standard deviation of 826 ppb. The existing studies for different building types measured a wide range of TVOC concentrations with the averaged concentration values ranging from 126 $\mu g/m^3$ to 1393 $\mu g/m^3$ [34]. Overall, the studied retail environments have comparable TVOC concentrations to those measured in other studies.

Table 1
Measured IEQ parameters at the retail store buildings with fixed and mobile sampling approaches.

Method	Parameters	Type	Instruments
Fixed sampling	TVOC	Chemical compounds	ppbRAE Plus PGM-7240[a]
	Air temperature	Thermal comfort indicator	iButton, Telaire monitor
	CO_2 concentration	Thermal comfort indicator	Telaire monitor
	Relative humidity	Thermal comfort indicator	Telaire monitor
Mobile sampling	TVOC	Chemical compounds	ppbRAE Plus PGM-7240[a]
	Formaldehyde	Chemical compounds	Shinyei Formaldehyde multimode monitor, DNPH tubes
	PM_{10}, $PM_{2.5}$	Particulate matter	TSI Side pak, TSI Dusttrak, met one Aerocet
	Air exchange rate	SF_6 decay method	SF_6 gas

[a] These instruments collected parameters by both fixed and mobile sampling methods.