Building and Environment 108 (2016) 1–11

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Investigation of indoor air quality in shopping malls during summer in Western China using subjective survey and field measurement

Yuzhen Shang [a, b], Baizhan Li [a, b, *], A.N. Baldwin [a, b], Yong Ding [a, b], Wei Yu [a, b], Li Cheng [a, b, c]

[a] Key Laboratory of the Three Gorges Reservoir Region's Eco-Environment, Ministry of Education, Chongqing University, Chongqing, China
[b] National Center for International Research of Low-carbon and Green Buildings, Chongqing University, Chongqing, China
[c] Henan Electric Power Survey and Design Institute, Henan, China

ARTICLE INFO

Article history:
Received 22 June 2016
Received in revised form
10 August 2016
Accepted 11 August 2016
Available online 13 August 2016

Keywords:
Indoor air quality
Shopping malls
Formaldehyde
CO_2
TVOC
Human perception

ABSTRACT

Thermal parameters and concentrations of CO_2, TVOC and formaldehyde were monitored in shopping malls in four western cities in China during summer. Simultaneously, questionnaire subjective surveys were carried out to investigate the indoor perception of air quality and Sick Building Syndrome (SBS) among staffs in the shopping malls. It was found that stuffy odor had significant correlation with the overall odors perception and staff in the shopping malls had noticeable SBS. Instrument measurement showed that mall C had higher pollution levels of TVOC, while formaldehyde concentrations were higher in mall X and L. Pollution level in the malls is influenced by many factors, and three factors (customer density, ventilation conditions, emission characteristic of merchandise) were discussed in the analysis of data from the four malls. For customer density, the concentrations of CO_2 on weekends were higher than on weekdays. Daily CO_2 concentration was positively correlated with customer flow rate, but there was no significant strong correlation between customer flow rate and TVOC/formaldehyde concentrations. Underground floors had poorer indoor air quality than over-ground because of lack of fresh air. As for the merchandise sections, the formaldehyde in the home textile section in mall X reached 1.15 mg/m^3 with an over standard rate of 83.3% due to the new merchandise added. This paper makes a contribution to knowledge relating to the reasons for discomfort in shopping malls by contributing multiple investigations on contaminants together with information on human perception and the operation of air conditioning systems within the stores.

1. Introduction

Formaldehyde and many volatile organic compounds (VOCs) are regarded as highly toxic materials and are human carcinogens that can cause respiratory illness, in particular leukemia [1–3]. Most VOCs are widely used in construction, furniture, textiles, carpentry and in the chemical industry because of their special characteristics [4,5]. Thus, formaldehyde and total volatile organic compounds (TVOC) are present in many indoor environments, with different toxicity and concentrations [6], arousing public attention on indoor air quality.

China has experienced rapid economic growth and urbanization in the past three decades [7]. Along with this process, a large number of people have greatly increased their requirements for merchandise, both in terms of quality and quantity. Shopping is one of the urban lifestyles [8], and the indoor air quality in malls attracts increasing public attention. The characteristics and concentrations of VOCs vary widely in different micro-environments of mall with a maximum of 596.8 μg/m^3 in Guangzhou, South China [9]. It has also been reported that the over-standard rate of formaldehyde and TVOC in underground shopping malls has reached 66.7% and 77.8% respectively in Xi'an [10]. What's more, emissions of formaldehyde and TVOC are influenced by many environment factors [10–17], such as temperature, humidity, air velocity and merchandise materials. Numerous studies in USA [18–20], Italy [21], Korea [22] and China [9,23,24] have reported that there are various indoor sources of volatile organic pollutants in malls, such as cooking, cleaning agents, carpentry, cosmetics and human activity. Meanwhile, the poor indoor air quality may prevent malls to be healthy,

* Corresponding author. The College of Urban Construction and Environmental Engineering, Chongqing University, (Campus B), Chongqing, 400045, China.
E-mail addresses: baizhanli@163.com, baizhanli@cqu.edu.cn (B. Li).

http://dx.doi.org/10.1016/j.buildenv.2016.08.012
0360-1323/

comfortable and productive places to work in. The increasing trend in the prevalence of Sick Building Syndrome (SBS) and other diseases is the worst scenario [25,26]. Subjective investigations in malls have shown that dissatisfied rates amongst mall users are often higher than 20%, and some areas have even reached 50% [27,28]. However, there is little information on the reasons for discomfort and on the specific syndrome of SBS. Moreover, field measurements for volatile pollutants are not often performed for different times of the day or different times of the week. So far, few investigations have reported both the multiple investigations on contaminants of indoor air, together with detailed information about human perception in malls in China. Although the rapid urbanization leads to the expansion of malls in Western China, information on the indoor pollutants and human health is somewhat limited. Therefore, there is an urgent need for a comprehensive study about air pollution level and specific subjective awareness, especially in Western China.

Chongqing, Kunming, Lanzhou and Xi'an are the four major cities in Western China experiencing modernization and industrialization, where various malls have been or will be constructed. In this research, objective measurements and questionnaire subjective surveys were performed to investigate the indoor air quality of malls each of these four cities. The study was conducted in summer when all stores operate their air conditioning systems daily because of high outside temperatures (more than 26 °C). The aims of the study were (1) to estimate the current indoor air pollutants levels and human perceptions in malls; (2) to assess the influencing factors on indoor air quality, and find both common and different

Fig. 1. Layout of the sampling sites in one of the case-study malls (mall C for instance).