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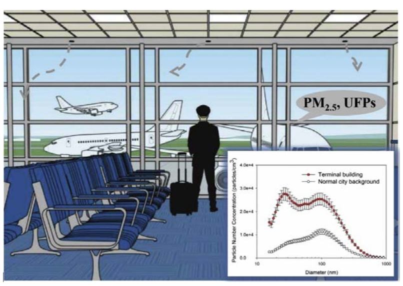
Short communication

Impact of atmospheric particulate matter pollutants to IAQ of airport terminal buildings: A first field study at Tianjin Airport, China

Jianlin Ren[a], Xiaodong Cao[b], Junjie Liu[a,*]

[a] Tianjin Key Laboratory of Indoor Air Environmental Quality Control, School of Environmental Science and Engineering, Tianjin University, Tianjin 300072, China
[b] Department of Environmental Health, Harvard T.H. Chan School of Public Health, Boston, MA 02215, USA

GRAPHICAL ABSTRACT



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ABSTRACT

Passengers usually spend hours in the airport terminal buildings waiting for their departure. During the long waiting period, ambient fine particles ($PM_{2.5}$) and ultrafine particles (UFP) generated by airliners may penetrate into terminal buildings through open doors and the HVAC system. However, limited data are available on passenger exposure to particulate pollutants in terminal buildings. We conducted on-site measurements on $PM_{2.5}$ and UFP concentration and the particle size distribution in the terminal building of Tianjin Airport, China during three different seasons. The results showed that the $PM_{2.5}$ concentrations in the terminal building were considerably larger than the values guided by Chinese standard and WHO on all of the tested seasons, and the conditions were significantly affected by the outdoor air (Spearman test, $p < 0.01$). The indoor/outdoor $PM_{2.5}$ ratios (I/O) ranged from 0.67 to 0.84 in the arrival hall and 0.79 to 0.96 in the departure hall. The particle number concentration in the terminal building presented a bi-modal size distribution, with one mode being at 30 nm and another mode at 100 nm. These results were totally different from the size distribution measured in a normal urban environment. The total UFP exposure during the whole waiting period (including in the terminal building and airliner cabin) of a passenger is approximately equivalent to 11 h of exposure to normal urban environments. This study is expected to contribute to the improvement of indoor air quality and health of passengers in airport terminal buildings.

1. Introduction

Airports are one of the major sources of particulate matter (PM) and ultrafine particles (UFP) in urban areas (Johnson et al., 2008). A number of epidemiological studies have found associations between $PM_{2.5}$ (Delfino et al., 2011) and UFP (Donaldson et al., 2001) exposures and adverse health effects. Even short-term exposure to high concentrations may still touch off the health issues of susceptible

* Corresponding author.
E-mail address: jjliu@tju.edu.cn (J. Liu).

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Table 1
Summary of temperature, relative humidity (RH), HVAC ON/OFF status, wind speed and wind direction information during sampling days.

Date	Temperature (°C)			RH (%)			HVAC status	Wind speed (m/s)	Dominant wind direction
	AH[1]	DH[2]	AM[3]	AH	DH	AM			
02/04/13	19.8	19.2	12.3	26.1	30.4	33.9	On	3.3–5.7	N[4], NW[5]
02/05/13	19.6	19.2	12.2	25.7	30.5	34.4	On	2.5–4.3	N, NW
02/06/13	19.2	19.6	13.0	25.4	30.9	35.4	On	3.1–4.9	N, NW
04/27/13	21.6	21.5	19.1	44.5	44.1	50.2	Off	1.2–1.7	S[6], SW[7]
04/28/13	21.3	21.9	19.5	41.5	42.1	48.2	Off	2.1–2.8	S, SW
04/29/13	21.9	22.4	20.3	21.6	24.2	27.1	Off	1.3–1.8	S, SW
07/14/13	27.8	27.4	37.1	38.7	37.6	40.5	On	1.7–2.4	S, SE[8]
07/15/13	27.0	26.5	36.0	44.0	43.2	45.7	On	2.5–2.9	S, SE
07/16/13	28.1	27.9	36.8	33.9	33.5	42.6	On	1.0–1.6	S, SE

Note:
1. AH: arrival hall; 2. DH: departure hall; 3. AM: ambient; 4. N: north; 5. NW: northwest; 6. S: south; 7. SW: southwest; 8. SE: southeast.

populations (Peters et al., 2004) and has been associated with cardiovascular threats in healthy individuals (Jacobs et al., 2010). Recent studies have been conducted to determine the characteristics of particulate pollutants in the ambient environment near airports. Zhu et al. (2011) measured the particle number concentration at Los Angeles and observed that the UFP concentration was larger than 10^7 particles/cm^3 downwind of the runway during airliner takeoffs. It was approximately 1 000 times larger than the normal urban concentration (approximately 10^4 particles/cm^3, Zhu et al., 2007). Ren et al. (2016) conducted field measurements of UFP levels at Tianjin Airport and found that the UFP concentration at a sampling point 400 m from the runway were still significantly higher than the levels measured far away from the airport.

Airliner-generated particles not only have a significant impact on the outdoor environment but can also easily move from outdoor environment into indoor environment. Through the particulate effective penetration ability of pollutants and the mechanical systems of buildings or airliners in use (Massey et al., 2012), the particles can affect indoor air quality (IAQ). For example, Ren et al. (2017) studied the UFP characteristics in the cabin of a waiting airliner and observed that the UFP concentration and size distribution in the cabin were greatly affected by the ambient UFP condition. This approach will produce adverse effects on the health of passengers and crews waiting in the airliner near the runway. Similarly, the adverse effects created by $PM_{2.5}$ and UFP are also likely to influence the occupants in buildings nearby. However, to the best of our knowledge, no studies have been conducted to investigate the effect of airliner-generated particles on nearby buildings, specifically airport terminal buildings, which hold thousands of passengers at once and operate on a 24-h basis throughout the year.

Passengers usually spend hours in terminal buildings while waiting, traveling and checking in. A study conducted at John F. Kennedy International Airport observed that passengers spend approximately 2 h on average in terminal buildings (Hafizogullari et al., 2002). In China, the time passengers spend in the terminal buildings may be even longer due to the low on-time performance of airlines. Flightstats statistics showed a very low on-time performance of approximately 30% of the three major Chinese airports (http://www.flightstats.com/), ranking them as having the lowest efficiency in the world. Hence, it can be forecasted that $PM_{2.5}$ and UFP pollutants have considerably more adverse effects on the health of passengers waiting in the terminal building due to the high particulate pollutant concentrations and longer exposure time.

To address this issue, field measurements were conducted in the terminal building of Tianjin Airport to investigate the following: (1) CO_2, $PM_{2.5}$, and UFP concentration and particle size distribution in the terminal building and (2) the effect of airliner-generated particles from outdoor environment on IAQ. This report describes the first on-site study on particulate matter pollutants in an airport terminal building. Our unique data can broaden the database of IAQ in large-space public buildings and may also draw public attention to particulate pollutant exposure in terminal buildings.

2. Methodology

2.1. Study case

Tianjin is the largest coastal city in northern China; located approximately 120 km southeast of Beijing. Twelve million passengers pass through Tianjin Airport every year. The T1 terminal building is located northeast of the runway at a distance of approximately 700 m. It is a two-story building; the ground level is the arrival hall, and the upper level is the departure hall.

Measurements were conducted during three periods. The first period lasted for three days in the winter from February 4 to 6, 2013. The heating, ventilation and air-conditioning (HVAC) system was turned on for heating during this period. The second measurement work was conducted in the spring, April 27–29, 2013, during the transition season the HVAC system was off for energy-saving purposes. The third period was in the summer, July 14–16, 2013, when the HVAC system was on for cooling. Table 1 gives a summary of the indoor and outdoor temperature and relative humidity (RH) during the measuring periods. The data was recorded by HOBO data loggers (UX100-003, Onset Inc., Bourne, MA). Table 1 also shows the outdoor wind speed and direction information provided by the nearest public weather station.

We set up ten sampling points in each hall, including one located outside. The number of sampling points in this study was more than the minimum required by EPA standards (at least one point per 2 323 m^2 EPA, 2007). The outside sampling points were located approximately 10 m away from the terminal building. They were carefully selected to be away from the airport pick up/drop off routes to reduce the influence of local UPF sources. The other nine inside sampling points were uniformly distributed, located at a height of 1.2–1.5 m. The measurements were performed from 7 a.m. to 7 p.m. The pollutant concentration at each sampling point was continuously measured for at least half an hour every day. Before formal measurements, a pre-test was performed to verify the uniformity of $PM_{2.5}$ and UFP distributions. The pre-test results showed that particle concentrations were uniformly distributed (relative differences < 20%); furthermore, slightly higher particle concentrations were measured near the doors. No significant indoor $PM_{2.5}$ and UFP point sources were found in the terminal building.

2.2. Sampling method

The $PM_{2.5}$ mass concentrations were measured by two portable optical monitoring devices (Dusttrak Model 8530, TSI Inc., St. Paul, MN) simultaneously. One instrument was kept outside. The other instrument was positioned at the inside sampling points one after another. The two instruments were calibrated by the gravimetric method