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A case study on ozone concentration levels inside and outside a student hostel room in Nanjing city, China

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Abstract *People generally spend most of their time indoors. Indoor pollutants such as ozone could adversely affect human health, particularly in relation to impaired lung function. For a realistic assessment of human exposure, both outdoor and indoor measurements of ozone concentrations are required. The objective of this paper is to provide reference data for people who want to improve the indoor air quality (IAQ) and reduce the personal exposure to ozone. Using ultraviolet adsorption method, we carried out consecutive measurements on ozone concentrations inside and outside a couple of student hostel rooms in Nanjing city, China. In general, the ozone concentration rises in the morning, reaches the peak at noon or in the afternoon and then declines. The peak time is usually between 12 pm and 4 pm. The indoor ozone concentrations can be a significant fraction of that outdoors and are highly dependent on the ventilation pattern. Our measurements in a non-air-conditioned room show that the average values of indoor/outdoor ratios for ozone are 50%. This paper also studies the relationship between indoor/outdoor ozone concentration levels under different circumstances. Furthermore, the effective methods to reduce indoor pollutant levels are discussed.*

Keywords *Ozone exposure I/O ratio*

1. Introduction

Ozone is an active species which is easy to have heterogeneous reactions on the surface. Indoor ozone concentrations are usually less than that of outdoors, and the indoor and outdoor concentration ratios (I/O ratios) of ozone are usually within the range 10%~90% [1-10]. Ozone decomposition rates depend on the number and types of building materials [9,10].

Indoor ozone concentrations depend on the room's own generation rate, leakage rate, ventilation rate, mixing and air filtration capacity [10].

Thompson et al. [1] reported that in Southern California indoor ozone concentrations may reach the outside level of 67% in the case of large in-take air and strong air circulation. However, in the case of small in-take air and slow air circulation, indoor ozone concentration can decline to approximately zero.

Liu et al. [5] monitored the indoor environment in a number of residential buildings in the summer in Toronto and found that when the air change rate per week correlates with the I/O ratios, indoor ozone concentration can be forecast effectively by the outdoor ozone level. Shair[7] and Hales[8] used a mass balance model to describe the relationship between indoor and outdoor ozone levels, and predicted that using air conditioning systems the indoor ozone concentration can be reduced to 20% of the outdoor concentration.

Sabersky et al. [9] monitored ozone levels inside and outside two office buildings in Pasadena. In one air-conditioned building with full outdoor air systems, the maximum indoor ozone can reach 80 ±10% of outdoors, while sometimes even exceeds the outdoor level. While in another building to 70% the outside air and 30% provide ventilation air conditioning exhaust air regeneration system of indoor ozone maximum levels for an outdoor 65 ± 10% .

Muller et al. [10] stressed that room surfaces affected indoor ozone levels. The potential surfaces contributing to indoor ozone decay included wall paint, furniture, curtains and books, etc. Sabersky et al.[9] measured ozone concentration in a typical private residence. They filled the room with outside air, and closed all the windows and doors. They discovered that ozone decayed quickly (30 minutes from 0.23ppm down to 0.04 ppm) because there was inefficient ventilation and surface decomposition of ozone in the room.

Levels of near ground ozone in Nanjing area

Nanjing is located in the densely populated and economically developed Yangtze River Delta areas. It faces severe environmental pollution problems. The motor vehicle inventory in Nanjing is increasing rapidly, resulting in aggravating air pollution. In particular, the process of production, storage and transport process in the local petrochemical companies is a important source of the Volatile Organic Compounds (VOCs) in the atmosphere. The highly reactive VOCs cause high ozone levels [11]. Most of the previous studies focused on of O_3, NOx and VOCs concentration variations in the densely populated urban centers, while the study of the O_3 pollution levels inside and outside the buildings in the downtown area of study is relatively scarce.

Due to the high number of sunshine hours in summer in Nanjing and lower precipitation, prone in Nanjing area O_3 High value [12] . This study located in the Centre of Nanjing University campus in a dormitory room inside and outside the room to monitor O_3 test in order to better analyze local construction of indoor and outdoor O_3 concentration

variation and influence each other in July, 2015 to August, 2015. This research in the window closed and windows open, as observed under two different conditions of natural ventilation and indoor and outdoor ozone concentration variation characteristics and relationships, when high ozone concentrations in the environment are discussed in the room occupants how to switch Windows, simple method of natural ventilation to reduce indoor ozone-exposure levels. This study in order to draw some useful conclusions and provides references for and control measures of indoor air pollution of the atmosphere, has a certain significance.

2. Methods

This study is located in the city center of Nanjing University campus, a room in a student apartment as the object of study. This type of room is a double standard room size is about 45m^3 cuboid, size is approximately 3mx5mx3m. On one side of the room walls have a push-pull opening around the rectangular glass window, open area for 0.84m^2; opposite on the other side of the wall, there was a 0.8m wide doors. Conditions of natural ventilation in the room throughout the day, the door closed and no air cleaner cases respectively to close the window and open the window as two different switch ventilation and monitoring indoor ozone concentration change and relationships.

On each ventilation condition, room needs remain the same. If the room is ventilated in accordance with specified arrangements (for example found that doors should be closed when opened), measured data is excluded.

The United States 2B Technologies Company production 202 and POM type ozone monitoring instrument and sampling used ozone monitoring instrument, interior and exterior. Both 2B ozone Analyzer uses proven technology design 254nm UV technology, can be from one point five billionths of a volume than the lower limit of (PPB) to one hundred over one million (PPM) in the dynamic range of the upper limit, accurate measurement of ozone in the atmosphere; sampling flow 1.0L/min. Concentrations recorded in the range of 1.5~100 ppm, Record value is accurate to 0.1 ppb。This study monitors set for 1min recording instantaneous concentrations.

Prior to starting formal monitoring, the two ozone monitors after a long time at one point but after sampling has been very similar to the correlation coefficient is greater than 0.90 of two concentrations distribution curve, there by demonstrating the instrument on indoor and outdoor monitor and compare the reliability of. Experimental set-up of this study as Figure 1 shows.

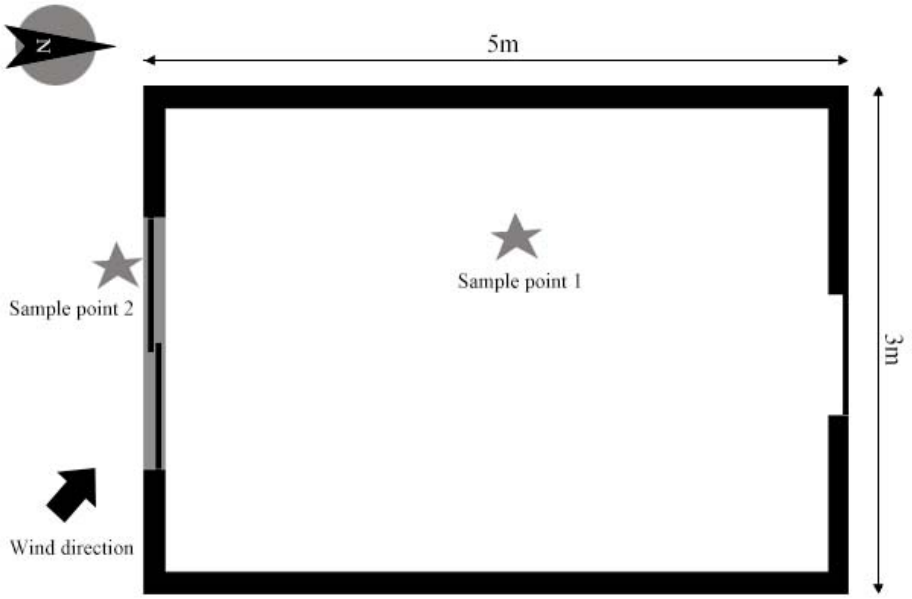

Fig. 1 Experimental layout of this study

3. Results

Relationship between indoor and outdoor ozone concentrations

Table. 1 Relationship between indoor and outdoor concentrations of ozone contrast under different aeration conditions

	Window opened (n=119)	**Window closed (n=51)**	**Total (n=170)**
Outdoor ozone (ppb)			
Average (+SE)	57 (+14)	59 (+18)	58 (+13)
Mid-value	60	62	62
Range	15-82	31-77	15-82
Indoor ozone (ppb)			
Average (+SE)	28 (+11)	15 (+3)	24 (+11)
Mid-value	27	14	21
Range	11-61	10-24	3-61
I/O			

Average (+SE)	0.50 (+0.15)	0.26 (+0.05)	0.43 (+0.17)
Mid-value	0.47	0.25	0.42
Range	0.23-1.00	0.21-0.39	0.21-1.00

From table 1, in daily outdoor concentrations of ozone peak values of expected period (10 points to 18 points) recorded half an hour average concentration values fall on 15ppb to 82ppb range. Outdoor average ozone concentration between two different ventilations and air condition is not significant, and is greater than 50ppb. In addition, the average indoor ozone concentration was significantly lower than average outdoor ozone concentrations. Ratio of average ozone concentration inside and outside in the open window conditions and close the Windows condition respectively, 0.50 (+0.15) and 0.26 (+0.05).

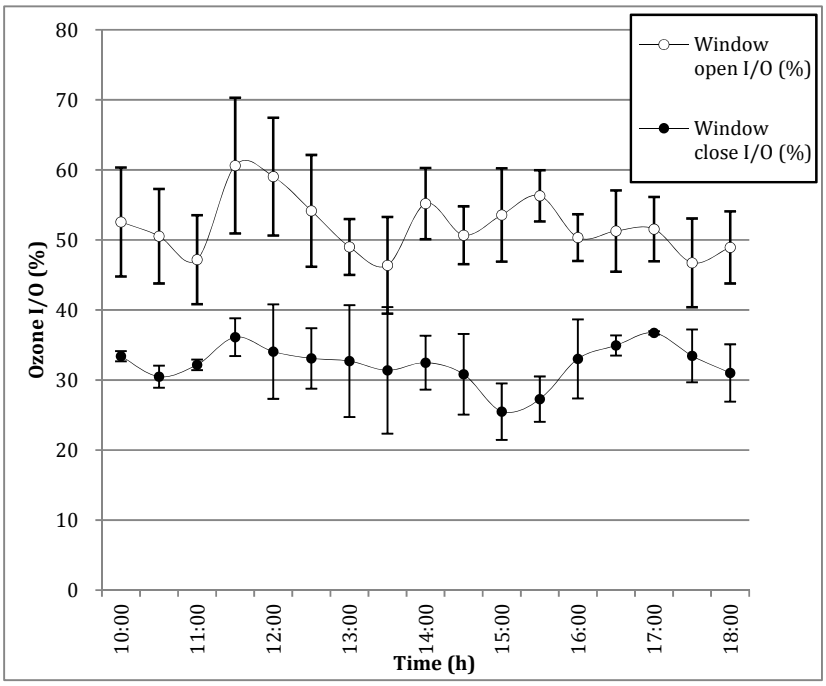

Fig. 2 Indoor and outdoor ozone in half an hour a day average ratio and those standard error. Time is the time in Beijing, China (GMT+8h)

Figure 2 expressed in daily outdoor concentrations of ozone peak values of expected period (10 Point to the 18 Point) average concentrations every 1.5 hours I/O The ratio of the number of observations, respectively n = 7 (Windows open) and n = 3 (Windows closed), and using a small vertical line to represent every half hour average concentration I/O The ratio of standard error. In Windows open and Windows closed, indoor ozone average outdoor concentrations respectively 52 ± 4% and 32 ± 3%(see Figure 2)。

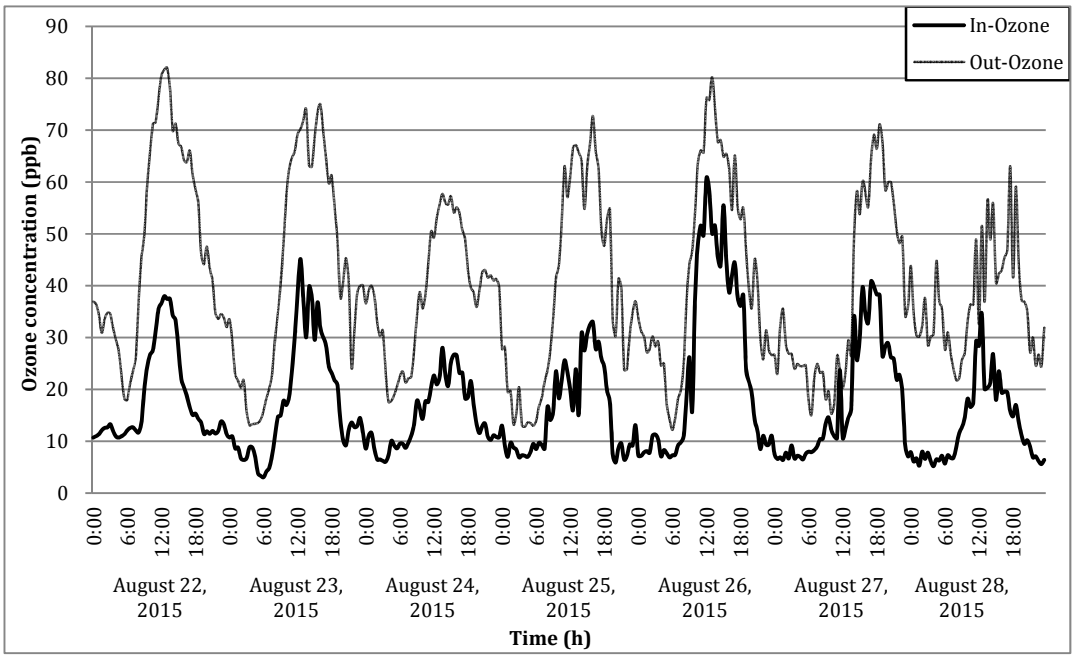

Fig. 3 Indoor and outdoor concentrations of ozone in the condition of windows opened. Time is the time in Beijing, China (GMT+8 h)

As Figure 3 shown in the seven days, observations found in the window under the condition of indoor and outdoor changes in ozone concentration has significant cyclical characteristics, outdoor ozone concentrations in the fast-growing characteristics in the morning is very obvious, peak occurred at noon and afternoon sessions, also made it clear after reaching the peak ozone levels also fall quickly feature. Indoor concentrations of ozone follow outdoor levels under the window open and rapidly growing phenomenon is particularly prominent. Indoor ozone concentration reaches a peak value began to fall at the same speed. High peak ozone concentrations in the outdoor and indoor ozone concentrations may be higher in a short time.

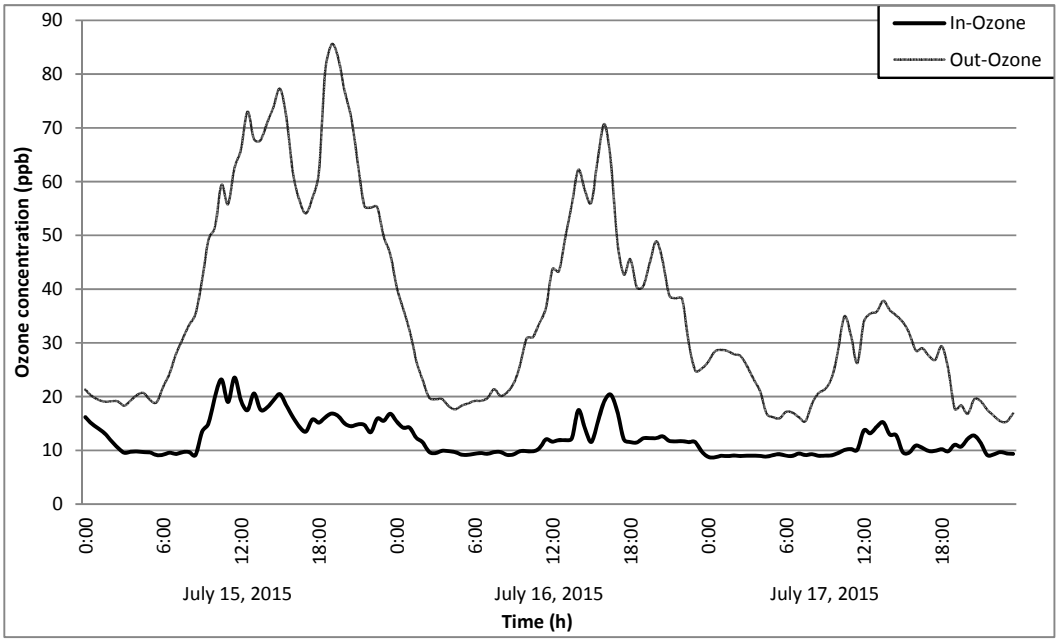

Fig. 4 Indoor and outdoor concentrations of ozone in the condition of windows closed. Time is the time in Beijing, China (GMT+8 h)

As Figure 4 shown under windows remain closed, indoor ozone concentration fluctuations are small, outdoors for periods of indoor ozone concentration ozone will remain at relatively low levels. Other results of indoor and outdoor observation of ozone day are also very similar.

Prediction of indoor ozone concentration

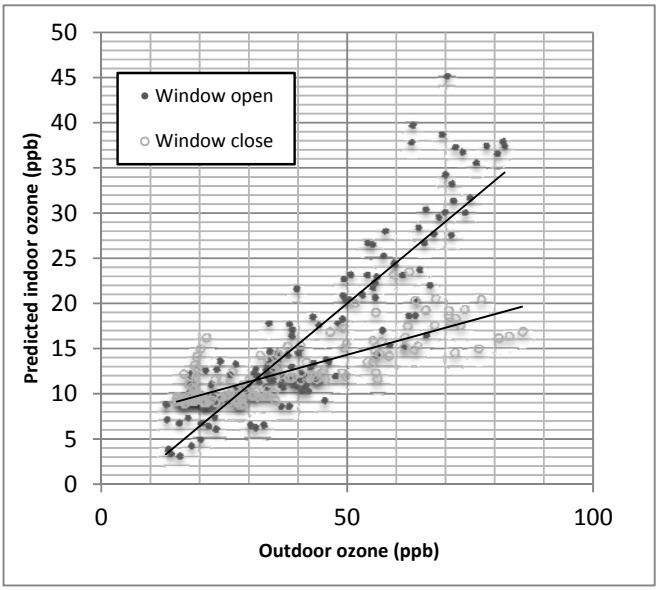

Fig. 5 Outdoor and indoor ozone concentrations under different aeration conditions

Figure 5 shows the linear regression analysis, when the window opens outdoor ozone concentrations are significantly predict indoor ozone levels and effective factors (regression coefficient = 0.53± 0.020), and in the window under indoor ozone concentrations generally less affected by outdoor ozone concentrations (regression coefficient = 0.15±0.009). When outdoor ozone concentrations to 100ppb Shi, average indoor ozone concentration at the window opens and closes the window separately under two different conditions can be estimated at 49(±6.4)ppb 22(±2.0)ppb.

Prediction of indoor ozone levels in the model and adjust the indoor ozone and ventilation, indoor ozone levels and there is a high correlation between ventilation. As Figure 5 shows, relative to the window condition indoor concentrations of ozone follow outdoor under the Windows Open increases significantly greater increases in ozone concentrations. In closed condition of the window, even when outdoor ozone levels exceed the 80ppb, indoor ozone concentrations of no more than 20ppb and in open conditions, when outdoor ozone concentrations below 60ppb Shi, indoor ozone concentration exceeds 20ppb.

In summary, this study has been on indoor and outdoor concentrations of ozone at the same time monitoring , significant forecasts rely mainly on the relationship between indoor and outdoor ozone levels found in air.

4. Discussion

The study shows that, in daily outdoor high peak ozone concentration is expected to 8 hours period (10:00 to 18:00), Nanjing University campus is located in the city center within a room in a student apartment in the window under open conditions, indoor and outdoor ozone concentration ratio of 0.46~0.61, and closed the window this ratio 0.25~0.37. Thus, this research suggests that the occupants of the room every day in 10:00 to 14:00 of time, keep doors and windows closed, indoor ozone concentration in the environment is generally lower. If you keep the window open the window within this time, indoor ozone concentrations may be high, even in extreme cases can exceed the standard limit value. Hayes[11,12] research some of the houses and found , average ozone concentration I/O ratios in the condition of such as windows that open and close, respectively to 0.65 and 0.23 results were similar.

Weschler, Shields and Naik[2] research reported in New Jersey indoor ozone concentration closely followed outdoor ozone concentrations and ventilation rates and the outdoor ozone level of 20%~80%. In the greater Toronto area the assessment of ozone exposure, Liu and others [4,5] study found average concentrations of ozone I/O ratio of 0.45, and the houses of I/O ratios there is a significant difference between poor. In addition, ozone I/O ratios and windows that

open weak correlation were found between the total times. These studies have shown that the houses of different materials may affect the ozone decay and I/O ratios.

When window open meant that indoor air is more high, indoor ozone concentrations in this study with the outdoor ozone level increases is bigger than the window close the case. Thompson[1], Reiss[3] , Shair[7] and others have found that indoor and outdoor air indoor ozone level is strongly influenced by, so indoor ozone concentrations are highly correlated with the ventilation seems to be reasonable.

Reiss, Ryan and Koutrakis[3] to pollutants such as ozone deposition studies show that ozone deposition to the surface and then are broken down. According to different flow conditions, surface absorption and boundary layer transmission rate is limited. Airflow and building surface indoor ozone concentrations were synergistic effects.

Diane R.Gold and others [13] studies also show that the air cleaner does not seem to provide clear benefits, in addition to a very specific type of room, when the door is closed, a high flow air filter may reduce the level of ozone exposure. However, high flow air cleaner may be too expensive, too loud or cannot be implemented in most public buildings.

In summer daily 8 hours outdoor ozone concentrations observed during high peak is expected results show that in windows open a case average ozone concentration ratios in the inside and outside 0.50 (+0.15). And windows are closed cases average ozone concentration ratios in the inside and outside 0.26(+0.05). While indoor ozone concentration at night often drops the 10ppb around, but in unusual light indoor ozone levels during a chemical attack might easily occur within several hours concentration above 50 ppb. If the rate of decay of indoor pollutants is not high enough, throughout the summer period the average ozone levels may be a cause of concern.

Many studies have shown that indoor ozone concentration will result in damage to human health. Acute ozone exposure, especially in sports are more likely to lead to respiratory symptoms and lung function decline [14, 15]. When outdoor ozone levels are highest are expected, elderly and children should consider to stay at indoors and keep windows and doors closed during the period, during which minimize the ventilation of the room rate is a solution that can reduce indoor ozone concentration. Although this method is not able to protect residents from the threat of other pollutants indoor, but at least it can reduce indoor ozone exposure levels in a similar manner. Now might be to consider how to defend in architectural design and to reduce air pollutants from the outside environment to negative impact of indoor transmission access, so as to protect the indoor health and material storage. In addition, when they needed an outdoor exercise should be avoided when higher outdoor ozone concentrations peak periods of the day.

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