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Analysis of Dynamic Variation Characteristics and Influential Factors of PM2.5 on Subway Platforms under Air-Conditioning Condition and Ventilation Condition

Lihui Wang[1,*], Jihua Zhang[1], Tianwei Hu[1], Meng Kong[2], Jensen Zhang[2], Jie Song[3] and Yi Zheng[3]
[1] University of Shanghai for science and technology, Shanghai, China
[2] Department of Mechanical and Aerospace Engineering, Syracuse University, NY, USA
[3] Shanghai Shentong metro company of technology center, Shanghai, China
[*]*Corresponding email: 66amy99@126.com*

ABSTRACT

The purpose of this study is to investigate the main influential factors of the subway Particulate Matter (PM) pollutants under the air-conditioning condition and ventilation condition, by an on-site field measurement in a subway station in Shanghai. It is found that the dust accumulation at fresh air shaft was the secondary dusting action under the influence of fresh air flow, leading to a higher concentration of the PM in the subway station than in the outdoor air even when the outdoor air quality was good. In addition, in the morning rush hour the PM 2.5 value near the platform screen door our is highest of the day.

KEYWORDS

Subway platform, PM 2.5 concentration, air-conditioning conditions, ventilation conditions

INTRODUCTION

The air quality of the subway station such as the PM concentration affects the health and comfort of a larger number of passengers and staffs. On the one hand, the friction on the rails during the operation of the train generates a large number of particles (Wen Zhengjiang et al.2012), on the other hand, ventilation shafts bring the outdoor particles into the tunnels, leading to the higher PM concentration in the tunnels. Furthermore, the suspended particles caused by the trains' operation may cause the increasing of the PM concentration on the platform during the opening of the platform screen door (Chang Jingjing and Sun Jian, 2014). Therefore, The variation of the PM concentration on the platform is relevant to the health of the passengers and staffs and arouses extensive attention from the researchers.

At present, researches on pollutants' control of the subway platform are mostly conducted through on-site measurements. For example, Zhao et al. used this method to study the concentration of particulates in subway platforms and train compartments, and observed their changes with the subway operation (Zhao et al., 2016). Kim et al. found that the concentration of PM10 and PM2.5 in the passenger compartment of the subway was lower than that in the station (Kim et al., 2010). Liu et al. measured and analyzed the concentration of the PM in the subway station and obtained a clear spatial-temporal distribution of the PM concentration in each area. It was found the concentration of the PM in the transition zone of the station was significantly higher than that of the PM on the platform and in ticket hall (Lu et al., 2015). There is no research or analysis on the influential factors of the PM2.5 on subway station platform and its significance. Therefore, the research on the influential factors of the PM2.5 on the station platform is urgently needed.

In this work, the dynamic PM 2.5 concentration on the subway platforms was measured on-site under the real-time inspection, aiming at finding the influential factors of the PM 2.5 on the platform.

Methods and Methodology

Characteristics of the PM2.5 concentration on the platform were measured at varied locations during several periods of the day with systematical field-monitoring of the carbon dioxide concentration, air temperature, and humidity. The measurement was conducted under the ventilation condition and air-conditioning condition. The pollutants' distribution characteristics were analyzed regarding the concentration and the heat pressure differences between the tunnel and the station platform during the opening process of the screen doors.

The field-measurements were conducted in the Caobao Road station of Shanghai Metro Line 12 on September 27th, 2017. The ventilation condition was from the starting points of train's operation in the morning to the noon, and the air-conditioning condition was from the noon to the midnight. In order to avoid interfering with the subway operation, two types of on-site measurement methods were developed including long-term and short-term monitoring. During the long-term monitoring, the equipment was fixed for a whole day, recording the data once a minute; during the short-term monitoring, the removable cart is utilized to collect the data at 1.5 m height dynamically.

The traditional ventilation and air conditioning system is used in Caobao Road subway station with the supply air pipe and the return air pipe on the two sides of the platforms (Figure 1). The platform is about 120 m long. Both the supply air pipe and the return air pipe are extended from the two ends to the middle of the platform. The locations of measuring points are shown in Figure 1 with the detailed descriptions in Table 1. The key parameters of the instruments used in the field-measurements are shown in Table 2. Figure 2 presents the photos of the measurement sites.

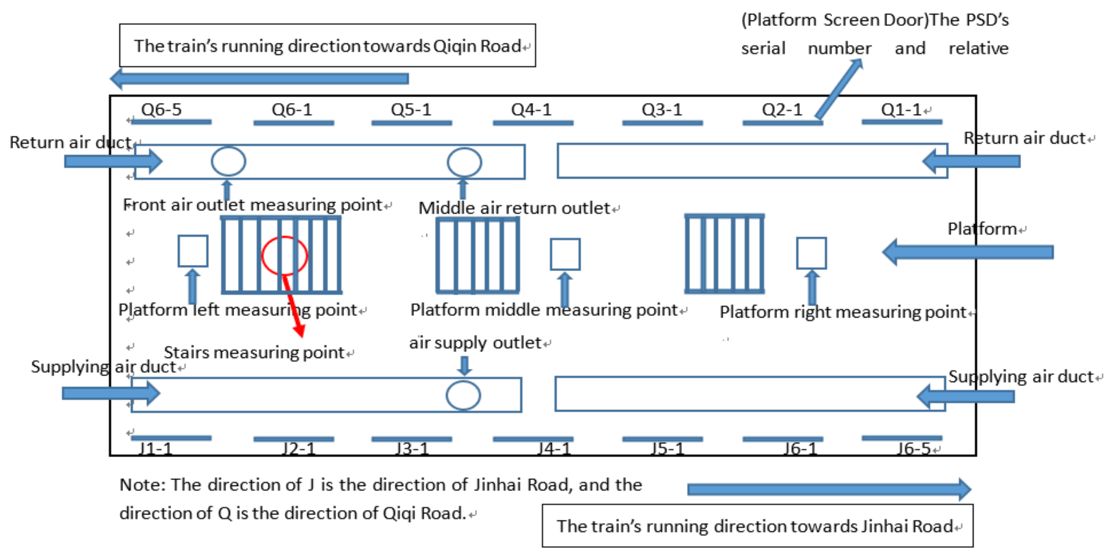

Figure 1 The locations of measuring points

Table 1 On-site measurement methods and object description

Detection method	Objects and measuring location	Number	Data collection method
Real-time inspection	Points on the platform left, middle, right, at 1.5m height	3	All day, 1 data per minute
	Supply air vents closed to the middle of the platform	1	

	Return air vents at the end and in the center of the platform		2	
	Fresh air shaft		1	
	Outdoor air		1	
On-site inspection	near the platform screen door in upline direction	1.5m height near the platform screen door	3-7	Morning rush, off-peak and evening rush hour period
	near the platform screen door in downline direction	1.5m height near the platform screen door	3-7	
	In the train, in the tunnel	the carriage, near the terminals of the platform	4	Off-peak period

Table 2 Measurement instrument parameters

Number	Name	Measuring range	Accuracy
1	Huayun GXH-3010E1CO2 Tester	0~1.000%	0.001%
2	HOBE thermometer	Temperature range：30□ ~ 70□ Humidity range：0 ~ 100%	Temperature accuracy：±0.2□ Humidity accuracy：±3%
3	BYWF2001 Anemometer	0 ~ 10m/s	0.05 ~ 5m/s±（reading×2%+0.1m/s）
4	Multifunctional dust measuring instrument	(0.01 ~ 100)mg/m3	±10%

（a）　　　　（b）

Figure 2 Measurement sites a) On-site inspection sites   b) Real-time inspection sites

RESULTS

Dynamic variation of PM2.5 concentration on the platform and related influential factors under air-conditioning condition

Figure 3 shows the dynamic monitoring results of the PM2.5 concentration in the supply air and return air vents, fresh air shaft, and outdoor air during the long-term monitoring. The PM2.5 concentration in the supply air was affected by both the concentrations in both the fresh air and return air. The supplying air parameters are relevant to those of the fresh air shaft and the outdoor environment.

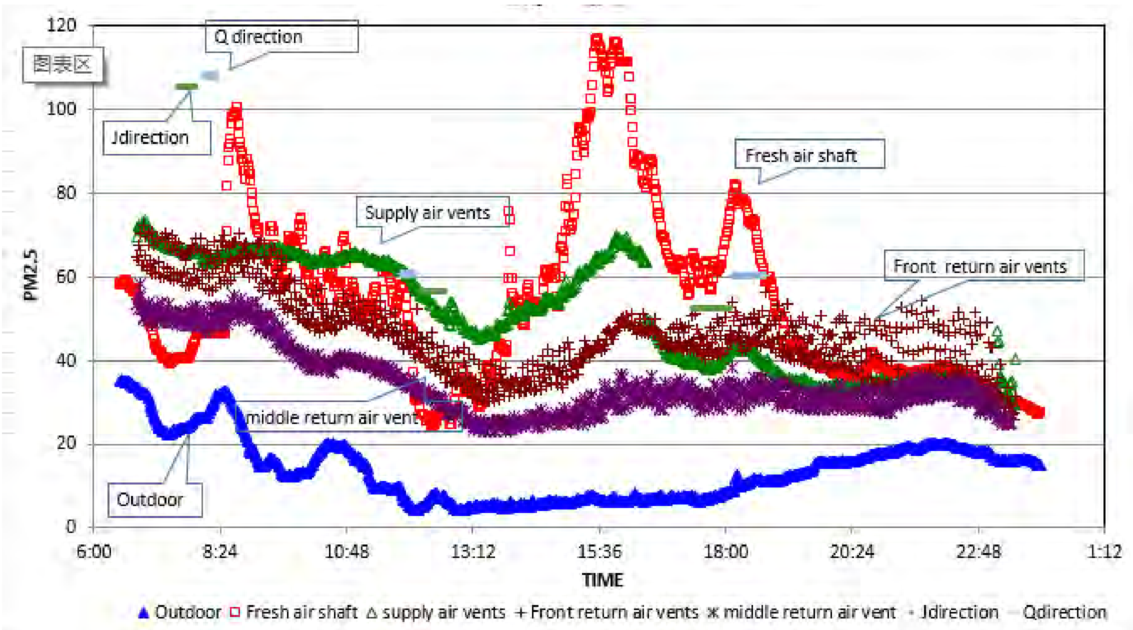

Figure 3 Monitoring results of the PM2.5 concentration in the supply air and return air vents, fresh air shaft, and outdoor air during the long-term monitoring

It can be seen from Figure 3 that the PM2.5 concentration in the return air vents was lower and correlated with the one in the supply air vents. The return air seemed not the main reason for the high PM concentration in the supply air under the air-conditioning condition. However, the fresh air was likely to contribute to the peaks of PM concentration in the supply. The PM level of the outdoor air was the lowest and much lower than that in the fresh air shafts. One explanation is that there was lots of dust accumulated in the fresh air shaft. It can be concluded that the secondary dusting action by the fresh air shaft led to the higher PM concentration in the fresh air intake even though the outdoor air was fairly clean. The PM concentration in the supply air was lower than that in the fresh air shaft and return air during most of the time, demonstrating that the filtration equipment in the air-conditioning system of the subway station did provide certain purification.

Dynamic variation of PM value on the platform under ventilation condition

Figure 4 shows the dynamic monitored PM2.5 concentration in the supply air, fresh air shaft and outdoor air under the ventilation condition. As shown in Figure 4, the PM2.5 concentration in the fresh air shaft was higher than that in the outdoor air, confirming that the dusting action in the air shaft was the main reason for the high PM2.5 concentration in the supply air. To avoid that, the supply air shaft of the subway station needs to be maintained and cleaned. On the other hand, the filtration system is critical for maintaining the PM concentration in the subway.

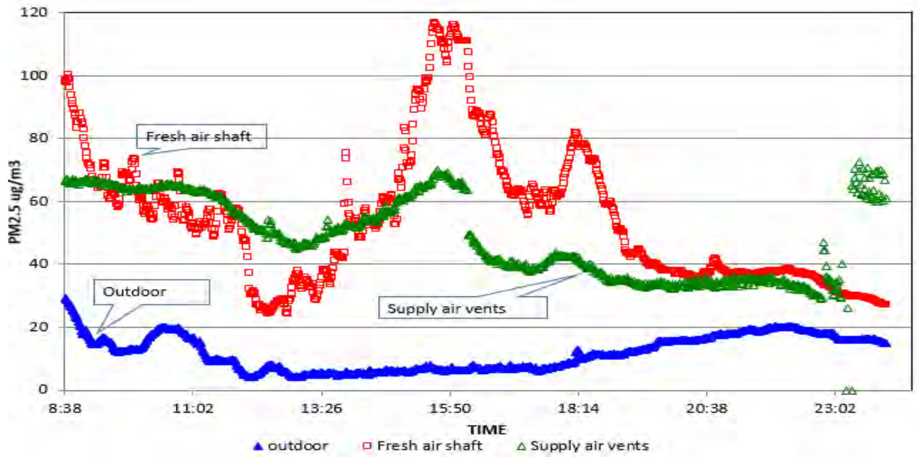

Figure 4 Variation of PM2.5 Concentration in Ventilation, New Ventilation Well, Outdoor Air under air conditioning condition and all-fresh-air condition

Dynamic characteristics of PM2.5 on the platform, return air and influential factors

Figure 5 shows the relationship between the concentration of PM2.5 in the return air and that of some typical locations on the station platform under both ventilation condition (from morning to noon) and air-conditioning condition (from noon to evening). The PM2.5 concentration in the return air correlated with the concentrations on the platform. The PM level both on the platform and in the return air vent reached the peak of the day during the rush hour in the morning. It can be concluded that the accumulation dust in the tunnel and in the fresh air shaft at night are secondary-dusting generated by the trains' operation during the rush hour in the morning. Besides, the PM levels of the typical locations and in the return air vent were also high from the evening rush hour to the end of the day. It can be attributed to the PM continuously escaping from the tunnel through platform screen doors (PSDs) during the operation hour, with the help of the passengers' movement on the platform.

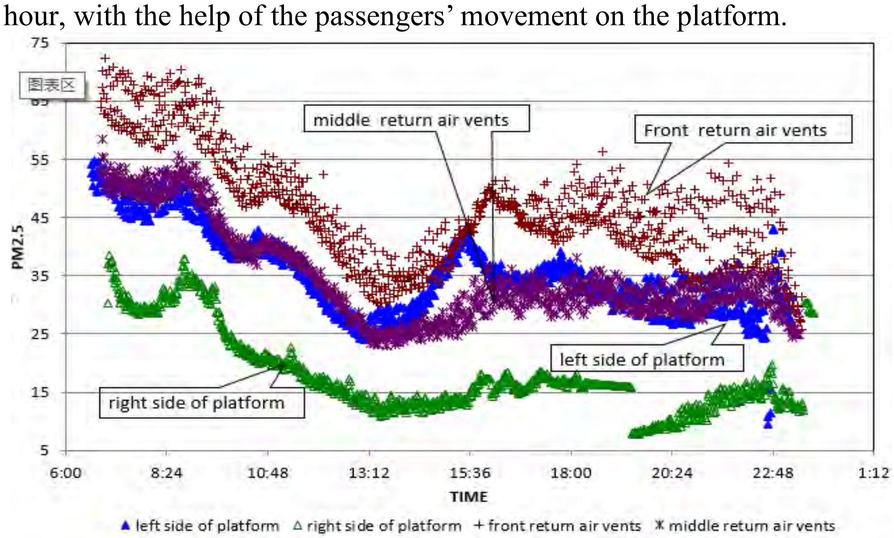

Figure 5 Variation of PM2.5 at different locations over time

The variation of the PM concentration near the platform

Figure 6 shows the data at the two typical measurement locations at 1.5m height on the platform, as well as the average values near the PSDs obtained during the rush hour in the morning, off-peak periods and rush hour in the evening. It can be seen that the PM2.5 concentration near the PSDs during the rush hour in the morning was significantly higher than that on the platform. Besides during the non-rush and rush hour in the evening, the PM2.5 concentration during the door opening process was slightly higher than that of the typical locations on the platform.

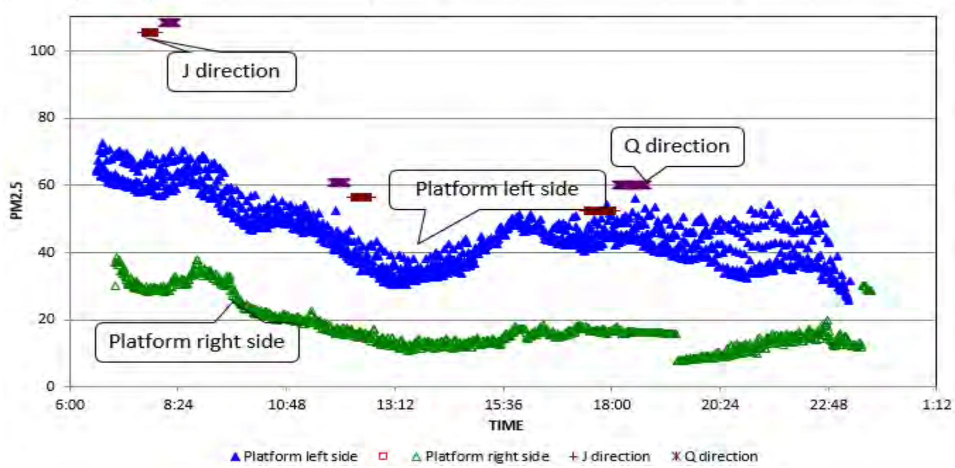

Figure 6 Comparison between PM2.5 concentration on the platform and near the PSDs

CONCLUSIONS

The conclusions of this current work are as follows:

1. The dusting action in the fresh air shaft led to the higher PM2.5 concentration in the fresh air vents even though the outdoor air was fairly clean.
2. The PM2.5 concentration in the return air correlated with the ones on the platform.
3. The PM2.5 concentrations during the rush hour in the morning were obviously higher than that of the off-peak hour and the rush hour in the evening.
4. The dusting action in the tunnel caused by the train in the morning is remarkable, resulting in that the PM2.5 concentrations on the platform near PSDs were always higher than that on the platform.
5. In order to avoid the dusting action in the fresh air, the fresh air shafts should be cleaned in a regular schedule.

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REFERENCES

Chang Jingjing and Sun Jian. 2014.Spatio-temporal analysis and assessment of CO and PM2.5 exposure concentrations under traffic micro-environment in Shanghai [D]. *Shanghai Jiaotong University*: 1-97.

Wen Zhengjiang, Han Xu, Liu Yingxin.2012.Experimental Study and Source Analysis of Air Pollutants in Underground Buildings . *Cleansing and Air Conditioning* (1), 4-8

Zhao Jingde, Wang Jinlong, Yan Guoqing. 2016.Research on Measurement of Particle Concentration in Environmental Control System of Urban Rail Transit. *Journal of Safety and Environment*, (4): 342-347.

Yong Su Kim a, MinJung Kim a, JungJin Lim et al. 2010.Predictive monitoring and diagnosis of periodic air pollution in a subway station .*Journal of Hazardous Materials*, 183:448-459.

[5] Senlin Lu, Dingyu Liu, Wenchao Zhang et al. 2015,.Physico-chemical characterization of PM2.5 in the microenvironment of Shanghai subway.*Atmospheric Research*, 153:543-552.