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Particulate Matter (PM2.5 and PM10) Concentration of Subway Transfer Stations in Beijing, China

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Abstract: Although much research is being conducted on the characteristics of PM2.5 and PM10 at subway stations, there is no research focusing on a complex subway transfer station. In this paper, the characteristics of PM2.5 and PM10 at transfer stations are studied. For comparison, monitoring is performed under different outside conditions at four different transfer stations in the non-peak period during March 2018. The concentrations of PM2.5 and PM10 on the platform in the transfer stations is approximately 10 μg/m^3 lower than in the non-transfer station, when outside PM2.5 is lower than 150 μg/m^3. However, the ratio of PM2.5 to PM10 at the transfer stations (lowest: 78.1%) is higher than at the non-transfer station (lowest: 61.2%), indicating that the PM10 content differs from the non-transfer station. In a transfer station with the same depth, the PM concentration is the same or similar. In addition, the concentration of PM2.5 at subway stations has a strong correlation with the outside environment (R^2 = 0.897), which indicates that an outside condition is important for the subway environment.

Keywords: transfer station; PM2.5; PM10; concentration ratio

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1. Introduction

1.1. Background

During China's recent major urbanization, increased traffic created significant problems in large-and medium-sized cities. One issue is that commuting by subway greatly affects personal exposure to inhalable particulate matter. The particulate matter PM2.5 and PM10 can remain trapped in the human trachea and bronchi and can be swallowed or discharged from the respiratory system by coughing (Figure 1). However, the fine particulate matter PM2.5 can easily enter the alveolar of the lungs and move directly into the blood [1]. Many epidemiological studies conducted in recent decades have shown that there is a positive correlation between particulate matter concentration and morbidity from diseases of the respiratory system, heart and lungs, especially for more vulnerable populations such as children and the elderly [2,3].

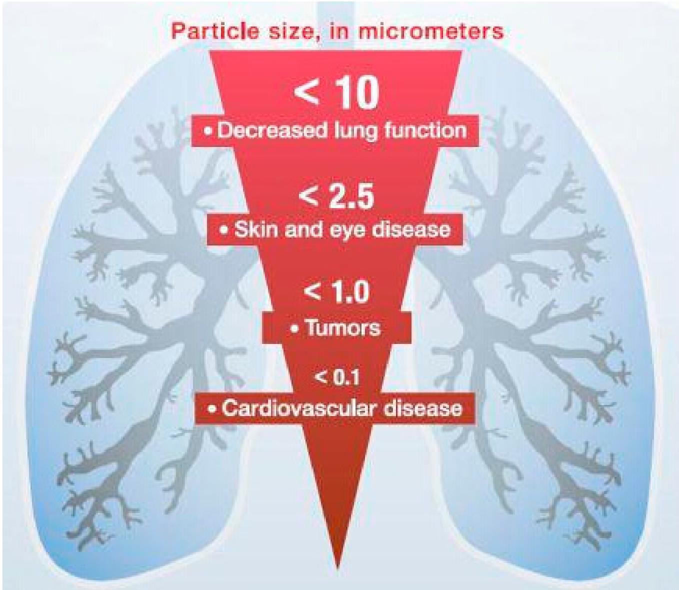


Figure 1. Schematic process of particles entering the body [1].

People are spending more and more time in the subway in the modern world [4]. For example, Koreans are reported to spend approximately 1.73 h a day in the subway [5]. Several researchers have found that high concentrations of PM2.5 and PM10 in long-term exposure in the subway will seriously harm human health [6,7]. A few results have shown that the danger of PM2.5 in the subway is up to ten times higher than at ground level [2,8]. Consequently, there is a strong need and demand to study the characteristics of PM2.5 and PM10 at subway stations.

1.2. Recent Developments

Researchers have concentrated on over 10 countries with large cities with a large number of passengers who take the subway every day. These cities include Montreal [9], New York [10], Los Angeles [11], Puna [12], Mexico City [13–15], Stockholm [16], Helsinki [2], London [17], Birmingham [18], Paris [19,20], Barcelona [21], Milan [22], Istanbul [23], Tehran [24], Seoul [25,26], Shanghai [27,28], Beijing [29,30], Guangzhou [31], Xi'an [32], Suzhou [33], Tianjin [34] and Taipei [35]. Pun et al. [36] reported that mortality would increase by 1.5% when the average concentration of PM2.5 increased by 10 μg/m^3. Several researchers have reported that the concentration of particles in the subway was much higher than the outside environment and that they were more toxic to genes, which could cause more serious public health problems [37]. Lepeule et al. [38] measured particle concentrations in six different cities over eight years in eastern America. They then analyzed the correlation between mortality and particle size and found that the correlation between mortality and PM2.5 was strong. There are now many studies that have measured particles in public transportation, including subways and buses [2,6,10,29,30]. However, many studies in the past have measured particles only for a short time, which has led to incomprehensive conclusions [28–37]. For example, they assumed that outside conditions, construction, subway station depth and environmental control systems affected the concentration but did not obtain data to support their assumption.

On the other hand, there are several studies that focus on the distribution and control of PM at subway stations in China. China is now building thousands of kilometers of subway systems in large- and medium-sized cities [39]. The increase in subway transportation has created a significant need to investigate air quality problems in local subway stations. The Chinese indoor air quality standard sets 75 μg/m^3 for the PM2.5 concentration limit in a building but the subway station is excluded because there are not enough data and relevant analyses on PM.

In addition, most existing studies have focused on non-transfer stations. Compared with non-transfer stations, although the number of transfer stations is much smaller, the flow of passengers is much higher and the structure is very complex. It cannot be concluded whether the concentration characteristics in transfer stations are the same as in non-transfer stations. Therefore, it is necessary and meaningful to study the characteristics of PM2.5 and PM10 at transfer stations. To better understand transfer stations, common types of transfer stations are introduced.

1.3. Types of Transfer Stations

Typical modes of subway transfer stations include four types (single platform, cross transfer, transfer through aisles and external transfer) (Figure 2). In Figure 2, the labelled numbers of Figures 3–5 represent the example that these different types can refer to. The flow of passengers at a subway transfer station is usually higher than at a non-transfer station. For safety reasons and time savings, most transfers are underground and passengers do not have to re-swipe.

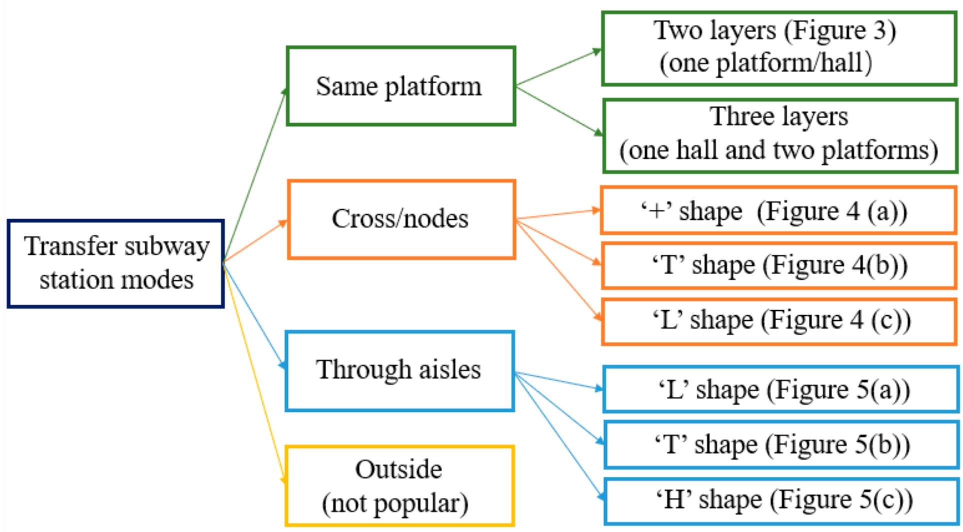


Figure 2. Common modes for subway transfer stations.

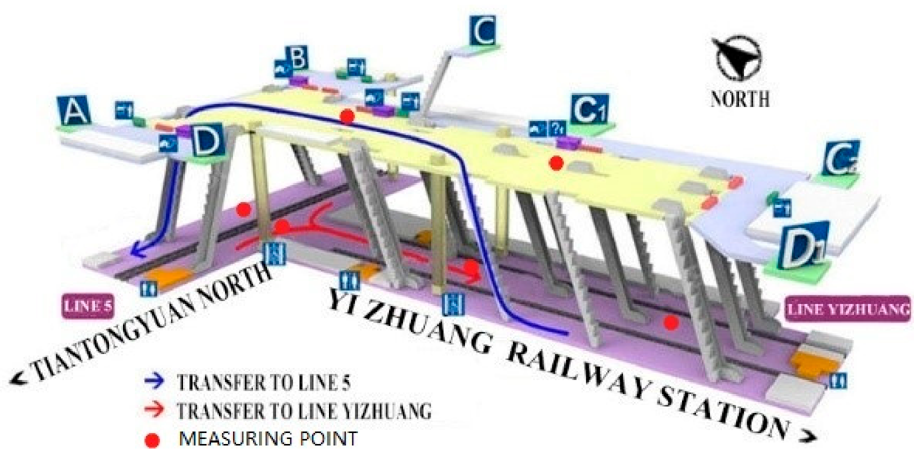
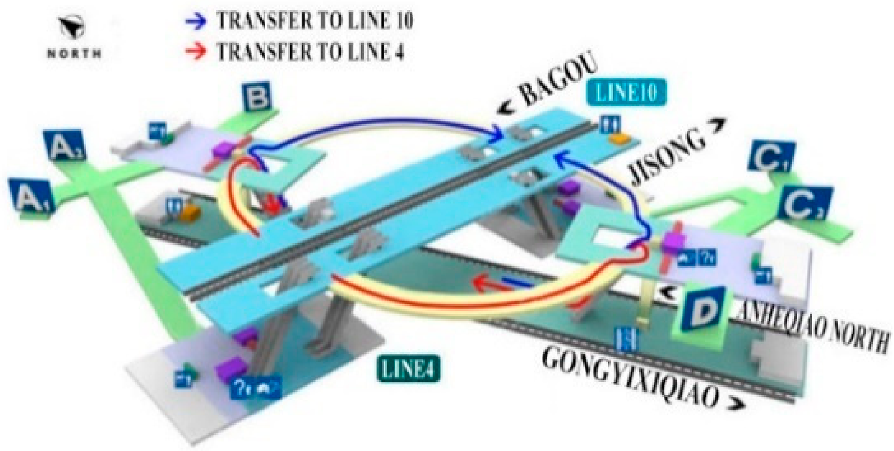
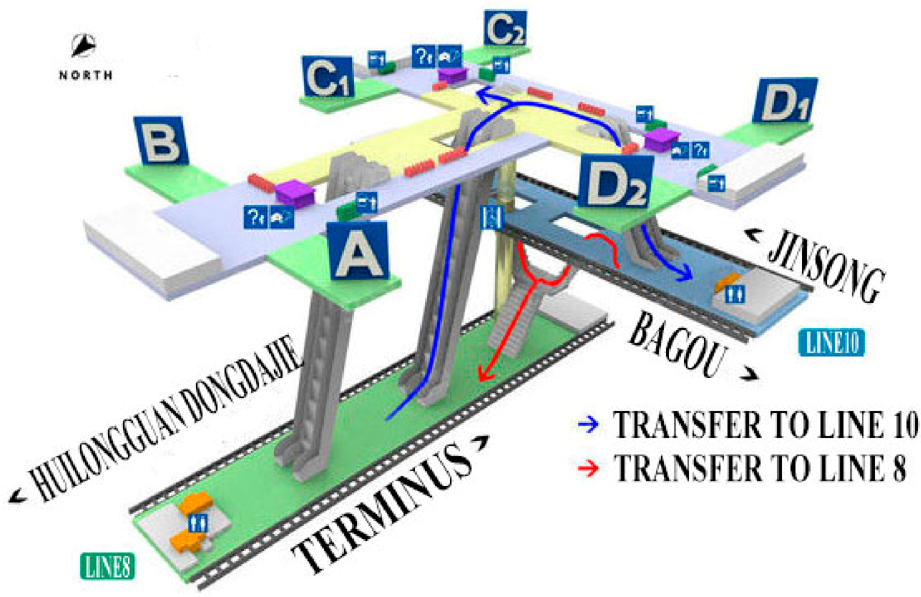


Figure 3. Example of a transfer station on the same platform: Songjiazhuang station in Beijing.



(**a**)



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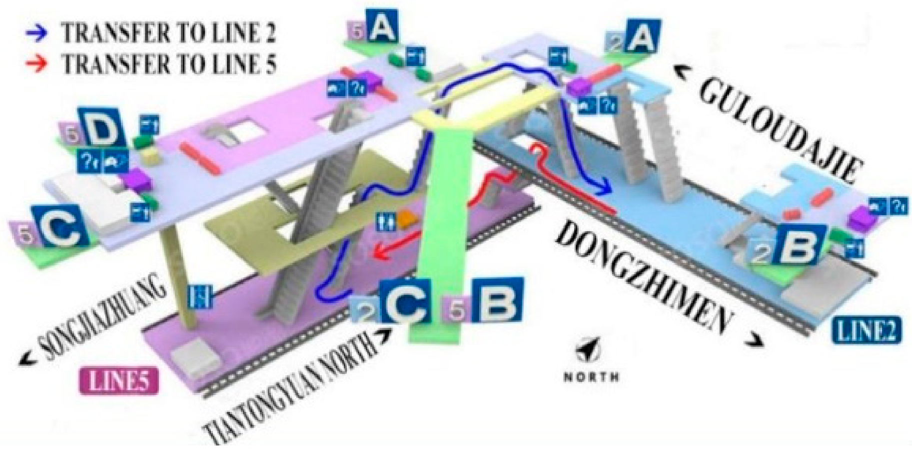
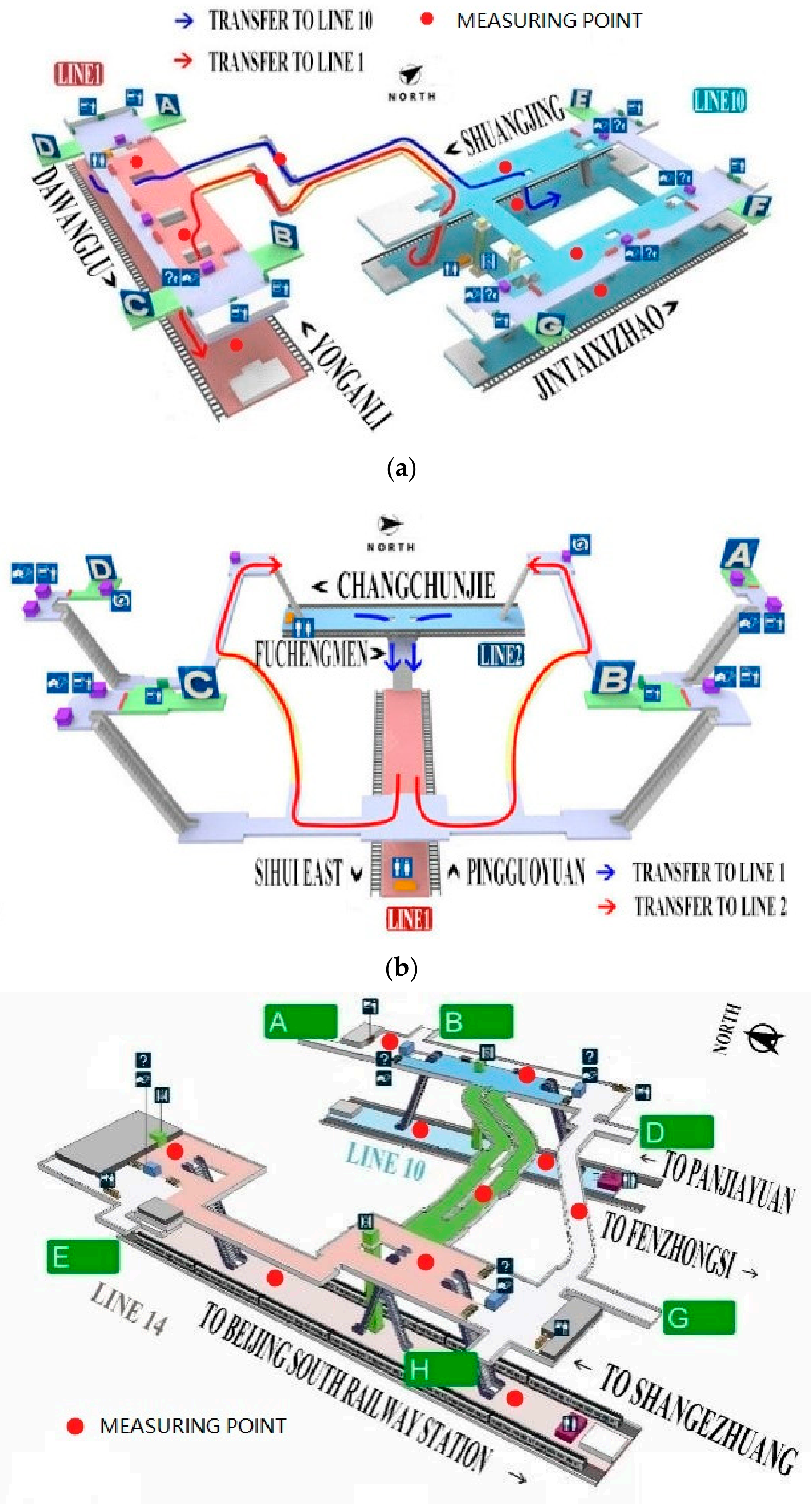


(**c**)

Figure 4. Examples of node transfer stations in Beijing: (**a**) '×/+', Haidianhuangzhuang station; (**b**) 'T', Beitucheng station; (**c**) 'L', Yonghegong station.



(**a**)

(**b**)

(**c**)

Figure 5. Examples of through aisle transfer stations in Beijing: (**a**) 'L', Guomao station; (**b**) 'T', Fuxingmen station; (**c**) 'H', Shilihe station.

Transfer through one platform is mainly used for two parallel lines and the platform should be in the island mode (Figure 3).

The second mode is cross transfer or node transfer. Based on the node type, it can be divided into different shapes. Common shapes include '×/+', 'L' and 'T', which are shown in Figure 4. The biggest difference between the shapes of the types shown in Figures 3 and 4 is the environmental control system in the subway. For subway transfer stations with the same platform, the environmental control system of most stations should take into account the impact of different lines on the platform except for a few stations with different hall layers. However, although the two transfer subway stations connected via cross/node types have links in the same hall, the environmental control system on the platform is completely independent and they do not affect each other.

The third mode is the transfer through aisle. In this mode, the stations on the two lines are connected through an aisle. This mode is easy to build but it is inconvenient for passengers because they need to walk further. According to the shape of the aisle, this mode can be divided into 'L', 'T' and 'H' shapes (Figure 5).

1.4. Research Gap and Main Aims

We know that transfer stations are more complex; however, almost all research is conducted on non-transfer subway stations. As passenger traffic increases, transfer stations are playing an increasingly important role. As the construction has a significant impact on the characteristics of PM2.5 and PM10 [6,18], their characteristics at transfer stations should be different compared with non-transfer subway stations but this is still not clear. Owing to difficulties in performing measurements such as limited measurement periods and equipment that cannot operate automatically, the existing studies were conducted only for a short time (e.g., a few days or a few weeks) and several studies even measured particles at only one location in the subway station.

In this paper, we mainly aim to fill the above-mentioned research gap by investigating the characteristics of PM2.5 and PM10 at transfer stations. The measurement was performed for two hours during one month with many facilities. The characteristics of PM2.5 and PM10 concentrations on the transfer stations are presented and the differences between transfer stations and non-transfer stations are obtained [32].

2. Materials and Methods

2.1. Monitored Stations

In this paper, transfer through aisle stations Guomao (GM), Shilihe (SLH) and Dawanglu (DWL) and transfer on the same platform with Songjiazhuang (SJZ) station were selected as the monitoring stations (Figure 6). The GM station is the intersection of Line 1 (opened in 1999) and Line 10 (opened in 2008). DWL is a cross station of Lines 1 and 14 (opened in 2015). Both shapes of the transfer aisle are 'L' (Figure 5a). SLH is a cross station between Lines 10 and 14 and the shape of the transfer aisle is 'H' (Figure 5c). All platforms are islands. SJZ station is the node of Lines 5 and 10 as well as the Yizhuang Line. The platform on Line 5 is a side mode and the Yizhuang Line is vertically connected to Line 5 on the south side (Figure 3). Line 10 is parallel to Line 5, which is located north of Line 5.

2.2. Measurement Equipment and Parameters

A portable Dusttrak II aerosol monitor (Model 8532, TSI, USA) as shown in Figure 7 was used to monitor the PM10 and PM2.5 concentrations, temperature and humidity. Such equipment includes data logging and a light-scattering laser photometer for real-time aerosol mass readings. The data logging interval was set to 1 min. The testing equipment was calibrated before the measurement.

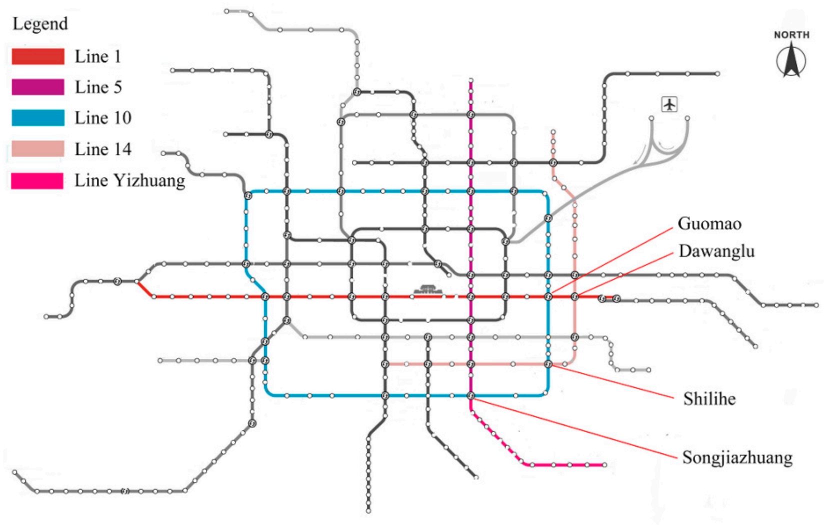


Figure 6. Monitoring stations in Beijing.

Figure 7. The TSI 8532 monitoring equipment.

For comparison, the measurements between the inside of the transfer station and the outside were simultaneous. The problem was that it was difficult to conduct measurements for a long time, especially during peak time, due to safety and management because measurements are prohibited during peak hours. Another difficulty was that we needed to measure the data in different locations at the same time, which required a lot of people and equipment. The above-mentioned transfer stations were monitored in the non-peak period (13:00 to 15:00 h) in March 2018.

2.3. Data Analysis Methods

The values of PM2.5 and PM10 concentrations were the average values of all the monitored sites. Based on Chinese standards [39], a total of six levels of air pollution was used based on the average value of the PM10 concentration in 24 h. The first level was excellent with a PM10 concentration range of 0–50 µg/m^3. The second level was 50–100 µg/m^3 and light pollution (100–150 µg/m^3) was ranked as level 3. Moderate pollution and heavy pollution were 150–200 µg/m^3 and 200–300 µg/m^3, respectively.

Situations above 300 μg/m^3 represented serious pollution that belonged to level 6. To compare the internal subway pollution with the external atmospheric environment, we selected data that were under different levels of pollution. For a further analysis, the Statistical Package for Social Sciences (SPSS) was used to analyze the monitored data. A general linear model (GLM) was used to examine the effect of the outside environment on the subway.

3. Results and Discussion

3.1. Outside Environment

The measurement campaign was conducted in March 2018. The outside conditions are shown in Table 1. According to the standard [39], the days from 8–11 and 14 March as well as from 23–26 March were excellent days (pollution level 1) whereas 13 and 20 March were good days (pollution level 2). From 5–7 and 12 March as well as from 17–19 March had light pollution whereas 2, 15, 16, 21 and 22 March had moderate pollution. Days with heavy pollution and serious pollution included 1, 3 and 4 March. The temperatures ranged from 13.2 °C to 26 °C and the outdoor humidity varied from 5% to 39%. The variations in temperature and humidity were not as large as the PM2.5 pollution.

Table 1. Outside conditions during monitoring in Beijing in March 2018.

Date (March 2018)	PM2.5 (μg/m^3)	PM10 (μg/m^3)	Temp (°C)	Humidity (%)	Pollution Level
1	293	597	17	18	serious
2	200	236	23.5	11.5	moderate
3	451	517	21	25.5	serious
4	374	417	16	28	serious
5	59	106	17	27	light
6	53	98	16	26	light
7	52	94	15	32	light
8	21	21	13.2	39	excellent
9	24	52	17	9	excellent
10	8	9	21	5	excellent
11	25	54	22	10	excellent
12	62	136	22.5	15	light
13	50	66	23.8	17.4	good
14	34	39	21	9	excellent
15	160	206	21	19	moderate
16	103	165	21	22	moderate
17	54	115	20	25	light
18	75	130	22	20	light
19	83	150	22	20	light
20	71	88	23	21	good
21	155	178	26	17	moderate
22	101	115	25	26	moderate
23	7	8	26	9	excellent
24	5	6	23	9	excellent
25	16	18	25	10	excellent
26	9	10	25	15	excellent

3.2. Transfer Station through Aisle

The results of the PM2.5 and PM10 concentration on the transfer station through aisle (GM, DWL and SLH) were presented and analyzed. The monitoring lasted for six days and the outside condition was good or excellent. The monitoring points were located on the platform in the aisle between the transfer station of two lines and on the carriage of three lines (Lines 1, 10 and 14). The results were the average of the values obtained at different monitoring points and their variance during the non-peak monitoring period.

The results are shown in Figures 8 and 9. It was obvious that the pollution was more severe in the subway than outside when the outside condition was good (PM10 less than 100 μg/m^3). There were several common characteristics of the particle concentration. First, the concentration of PM in the aisle was between the two transfer platforms regardless of the outside conditions. As the aisle was completely isolated from the outside, the environment in the aisle was under the combined influence of the transfer station on two lines. Second, the concentration at the transfer stations changed according to the outside conditions. The lowest daily PM2.5 concentration of 14 μg/m^3 was registered on the GM (10) platform when the outside condition was very clean. On the contrary, the highest concentration of PM2.5 (204 μg/m^3) was registered on the DWL (1) station during 22 March.

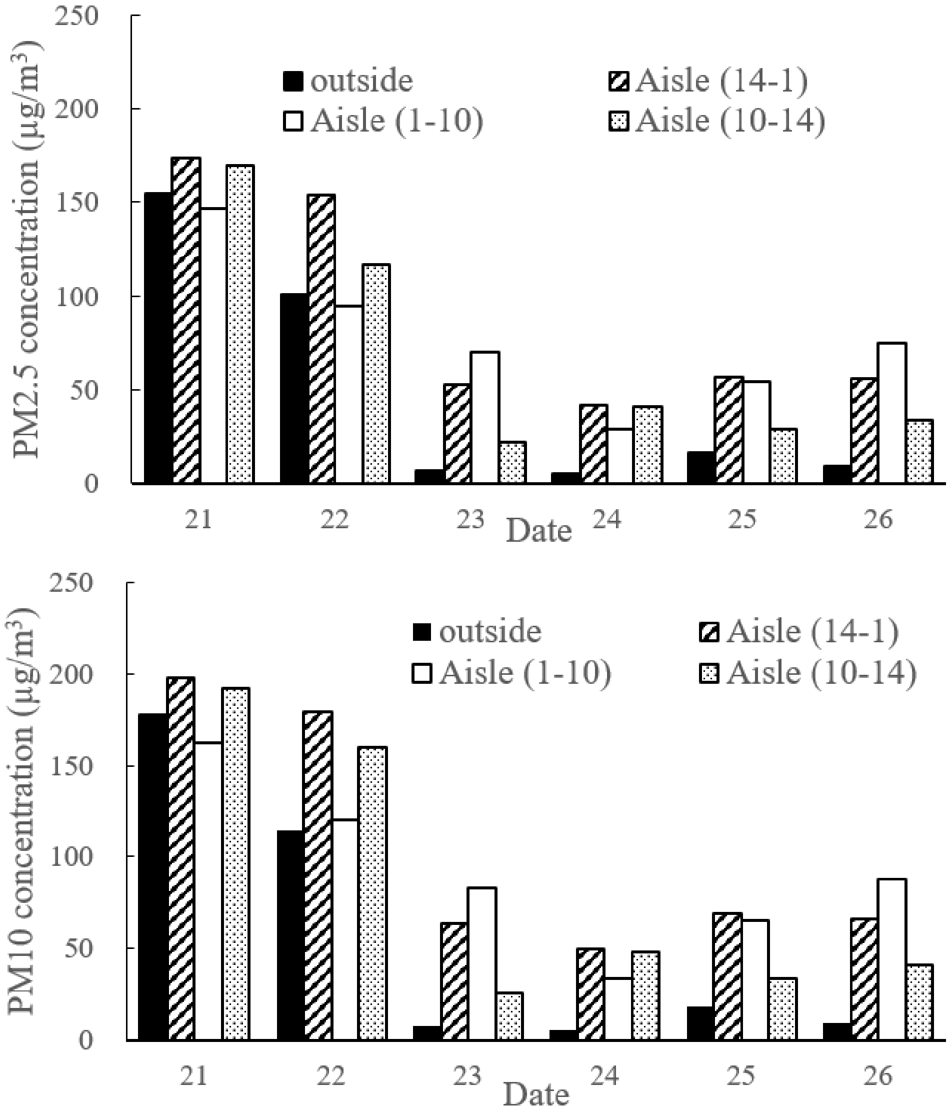


Figure 8. Measurement results at aisles. The numbers in brackets are Line numbers.

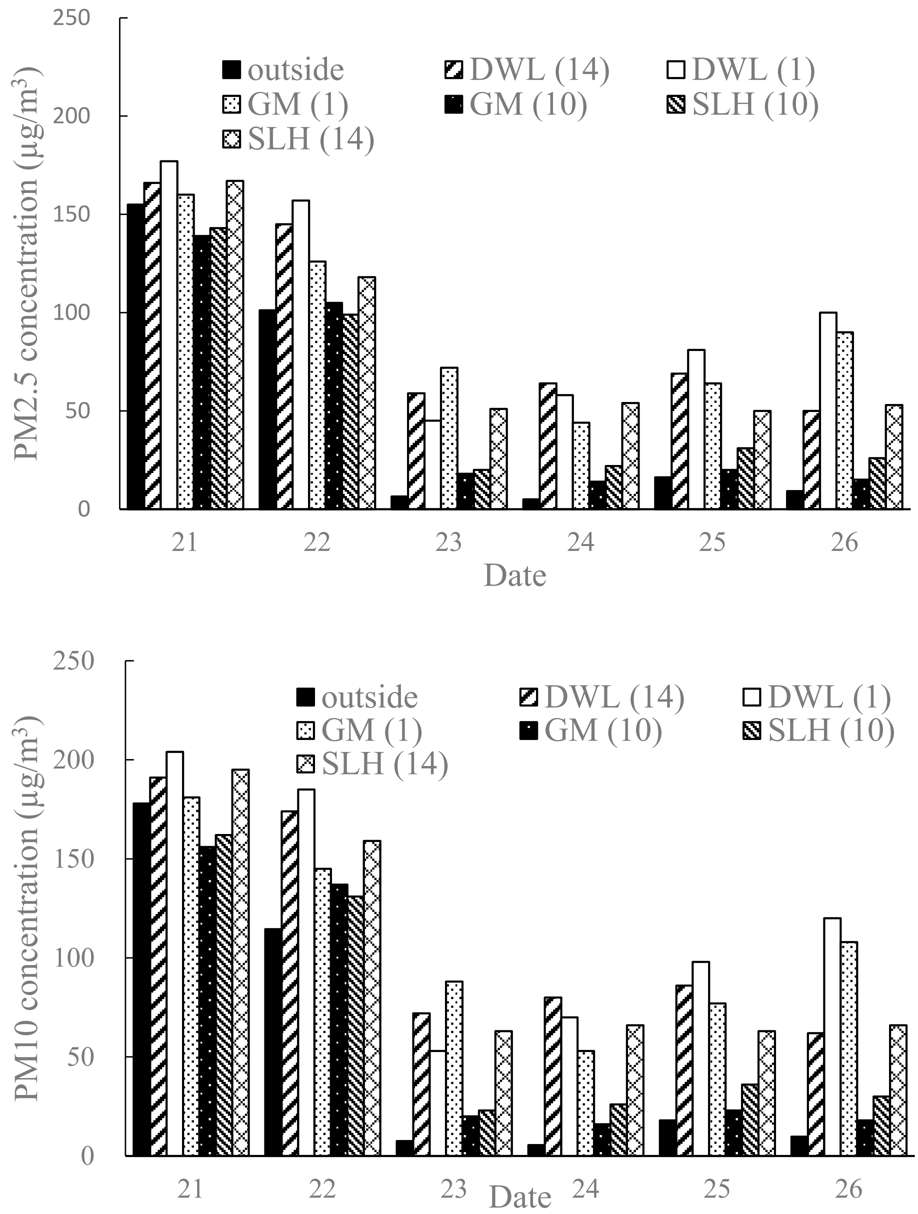


Figure 9. Measurement results at platforms.

Along with the change of outside conditions, the pollution in the aisles had the same trend of change; i.e., when the outside concentration of PM2.5 decreased, the concentration in the aisles also decreased. For the aisles, when the outside environment was good or with a light pollution level, the aisle on line 14–1 had the highest concentrations of PM2.5 and PM10 whereas the aisle on line 1–10 had the lowest concentration. When the outside condition was excellent, the aisle 1–10 had the highest value among the three transfer stations whereas the aisle on line 10–14 had the lowest. Most concentrations of PM2.5 and PM10 in the aisles were higher than outside when the outside environment was lightly polluted. The variation in the 'H'-shaped aisle (10–14) was less than approximately 15 $\mu g/m^3$ relative to the 'L'-shaped aisle (14–1 and 1–10). This may have been caused by the length of the aisle because the aisle at 14–1 and 1–10 was twice as long or more than the line at 10–14.

Figure 9 shows that the changes in particle concentrations on all platforms of transfer stations were in line with the outside conditions, which were the same as in the aisles. The difference was obvious on the platforms of one transfer stations and the difference was greater than on the platforms of different transfer stations. As factors such as passenger flow, outside conditions and environmental control systems were the same or similar, the above results may have been caused by the differences in construction between the different lines. Comparing the concentrations of PM2.5 and PM10 in different outside conditions, the highest pollution was registered on the platforms on Line 1 and the lowest on Line 10. From the aspect of the transfer station on Line 1, the pollution at DWL was higher than GM. On Line 14, the concentration at DWL was higher than SLH whereas on Line 10, SHL had a higher concentration than GM. For all platforms, the average concentration values at DWL (1) were the highest (177 μg/m^3 on 21 March) whereas GM had the lowest value (14 μg/m^3 on 24 March).

3.3. Transfer Station on One Platform: SJZ Station

The monitoring locations included three platforms and one joint hall on Lines 5, 10 and YZ. Although there were six directions for the platforms, each line had two directions. Line 10 was a ring with directions up and down. Both Line 5 and Y had a final and a starting direction. The depth of all platforms was the same at the SJZ transfer station. To make the results clearer, the platforms on one line were compared and are shown in Figures 10–13. All y-axes (Figures 10–12) were the same. There was no obvious difference between Lines 5 and 10, which indicated that for a transfer station with the same platform depth, the concentrations of PM2.5 and PM10 on the different lines were the same or similar. This could be considered to be one station in future research.

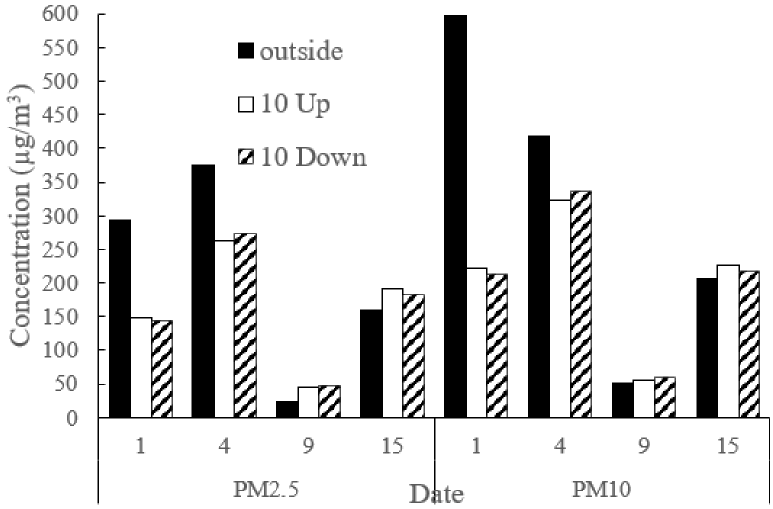


Figure 10. Measurement results on platforms at Line 10 (SJZ).

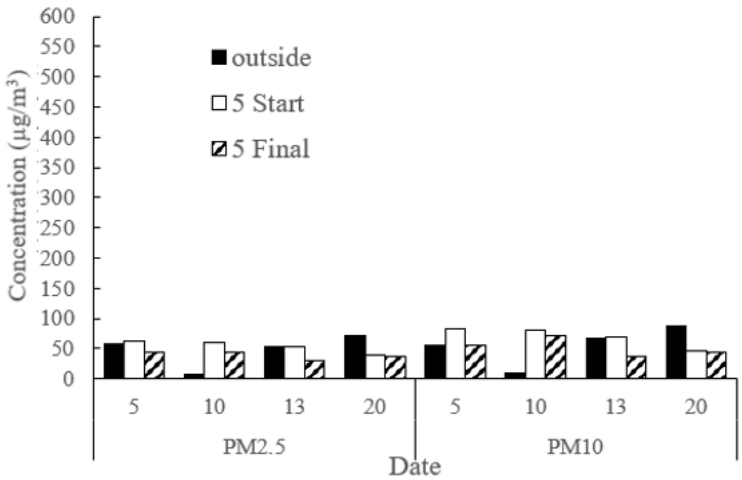


Figure 11. Measurement results on platforms at Line 5 (SJZ).

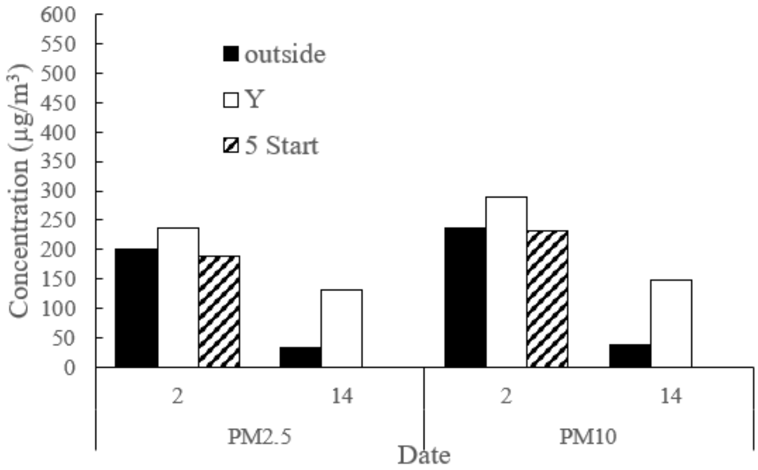


Figure 12. Measurement results on platforms at Line Y (SJZ).

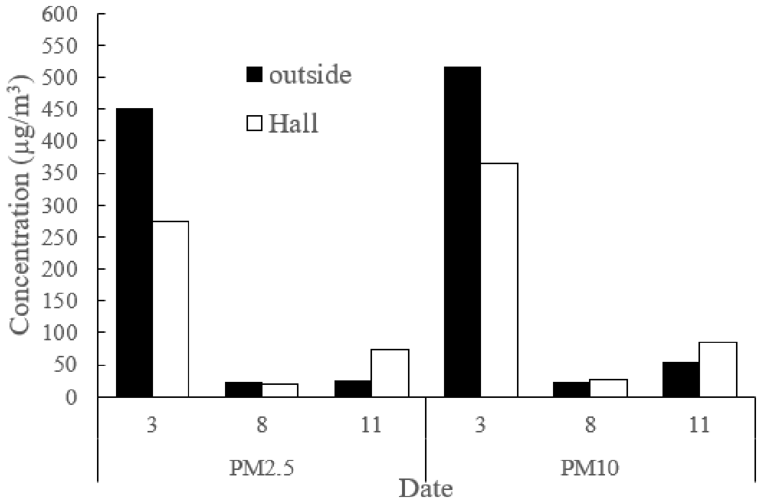


Figure 13. Measurement results in the hall (SJZ).

It was obvious that the concentrations of both PM2.5 and PM10 on the platforms with different directions on Line 10 were similar (Figure 10). When the outside pollution was under 200 μg/m^3, the concentrations of PM2.5 and PM10 on the platforms with different directions on Line 10 were higher than outside whereas when the outside pollution was over 200 μg/m^3, the concentrations of PM2.5 and PM10 on the platform were lower than outside. For Line 5 (Figure 11), the outside concentration was under 100 μg/m^3 and the concentrations of PM2.5 and PM10 were higher on the starting platform than on the final platform. This could have been caused by the structure because the platform on Line Y and Line 5 (starting direction) was directly connected. The concentration on the starting platform of Line 5 was higher than on Line Y (Figure 12) as the opening time of Line 5 was earlier than Line Y. For the SJZ hall (Figure 13), the concentration was lower than outside when heavy pollution was registered outside. When the outside condition was good, the concentration in the hall was a little higher than outside.

3.4. Ratio of PM2.5 to PM10

The ratio of PM2.5 to PM10 at different monitoring locations was calculated and analyzed (Table 2). The locations generally included two types of transfer stations. One type was transfer station through aisles. The locations for this type of transfer station contained an aisle and the platforms were at different lines. The ratio of PM2.5 to PM10 illustrated the composition of PM2.5/PM10; the higher the ratio, the more harmful it is to health because the harmfulness of PM2.5 is higher than PM10.

Table 2. Ratio of PM2.5 to PM10 at different locations (%): (a) outside and aisles; (b) platforms at transfer stations through the aisle; (c) SJZ stations.

Outside and Aisles						
Location	**Outside**	**Aisle 14–1**	**Aisle 1–10**	**Aisle 10–14**		
PM2.5/PM10	77.65	83.3	83.34	83.32		
Platforms At Transfer Stations Through Aisle						
Platform	**DWL 14**	**DWL 1**	**GM 1**	**GM 10**	**SLH 10**	**SLH 14**
PM2.5/PM10	82.18	84.23	84.43	85.59	84.70	80.38
SJZ Stations						
SJZ	**10 Up**	**10 Down**	**5 Start**	**5 Final**	**Y**	**Hall**
PM2.5/PM10	78.76	78.56	76.28	79.71	85.13	78.10

The ratio of PM2.5 to PM10 at the transfer stations was generally higher than outside (77.65%). The ratios on all the aisles were similar, approximately 83%. The PM2.5/PM10 ratio was highest for Line 10 (85.59% and 84.70% at GM and SLH stations, respectively) followed by Line 1 (84.23% and 84.43%, respectively). The ratio was the lowest for Line 14 (82.18% and 80.83% at DWL and SLH, respectively). The PM2.5/PM10 ratio at the aisle was similar to the transfer station platform. This result suggested that air control should focus on the inlets/outlets of the aisle. For the SJZ transfer station, the ratio of PM2.5 to PM10 was similar on different platforms and the hall (approximately 78%) except for Line Y where the ratio was 85.13%.

3.5. Correlations between the Subway and Outside

The correlation between PM2.5 at the subway transfer stations and the outside was calculated (Table 3). The results were the average values of the aisle (14-1) and the SJZ platforms. The results were significant (p-value < 0.05) for the different locations, which indicated that the correlation was strong. The outdoor environment had a dominant influence on the PM concentration on the subway platform and the aisle of transfer stations (R^2 = 0.897). Combined with a general linear analysis, the linear regression equations for the correlations between the indoor locations and the external subway stations were Y = 1.075X − 47.195 for the aisle, Y = 1.408X − 156.485 for the platform and Y = 1.611X − 45.693 for the transfer station hall.

Table 3. Correlation between subway and outside environment.

	Correlation Equation	**R**	**R Square**	**Adjusted R Square**	**Sig.**
Aisle	Y = 1.075X − 47.195	0.985	0.970	0.963	0.000
Hall	Y = 1.611X − 45.693	0.984	0.968	0.960	0.000
Platform	Y = 1.408X − 156.485	0.985	0.970	0.954	0.015

4. Discussion

This study found that the particulate concentrations at transfer stations were different from those of non-transfer stations. The concentration at transfer stations was generally higher than at non-transfer stations. In addition, the PM2.5/PM10 ratio at the transfer stations was also higher than at the non-transfer stations.

4.1. Comparison of the PM Concentrations at Transfer and Non-Transfer Stations

Compared with a non-transfer station [30] platform pollution at transfer stations was lighter than at non-transfer stations, especially for PM10 (Table 4). When the outside pollution was under 20 μg/m^3, the concentrations of PM2.5 and PM10 on the non-transfer station platform was 66 μg/m^3 and 140 μg/m^3, respectively. The highest values of PM2.5 and PM10 for the transfer stations were 64 μg/m^3 and 108 μg/m^3, respectively. When the outside PM2.5 was 100–150 μg/m^3, the concentrations of PM2.5 and PM10 on the non-transfer station platform were 174 μg/m^3 and 198 μg/m^3, respectively. The highest values of PM2.5 and PM10 for the transfer stations were 154 μg/m^3 and 178 μg/m^3, respectively. This could be caused by differences in the structure between transfer and non-transfer stations as the inlets/outlets of the transfer stations were larger. The ventilation capacity was higher than in the non-transfer stations to meet the needs of a higher passenger flow. As a result, particulate pollution was smaller at the transfer station than at the non-transfer station. The results at SJZ also supported the conclusion that compared with the non-transfer station [30] pollution on the platform of the transfer stations was smaller than on the non-transfer stations, especially for PM10. When the outside pollution was 200–300 μg/m^3, the PM2.5 and PM10 concentrations on the platform of the non-transfer stations were 158–200 μg/m^3 and 168–300 μg/m^3, respectively, and the values for the SJZ platform were less 150 μg/m^3 and 210 μg/m^3, respectively.

Table 4. Comparison of PM concentrations at transfer and non-transfer stations (μg/m^3).

		Transfer Stations	Non-Transfer Stations [30]	Non-Transfer Stations [29]
PM2.5	Outside		≤25/100–150/200–300	
PM2.5 (highest)	Platform	64/154/150	66/174/200	139/183/–
PM10 (highest)	Platform	108/178/210	140/198/300	176/198/–

Compared with another study [29], the results were the same. When the outside conditions were the same, the concentrations of PM2.5 and PM10 were lower in the transfer station than those in the non-transfer stations.

4.2. Comparison of the PM2.5/PM10 Ratio between Transfer and Non-Transfer Stations

The ratio of PM2.5 to PM10 at transfer stations was higher than that of non-transfer stations. At the non-transfer stations [30], the ratio on the platform was 68.6%; it was 79.6% outside and 61.2% in the hall. As passenger flow was much higher at the transfer stations, the risk of exposure was much higher at these stations, which requires further studies.

4.3. Correlation between Subway Stations and the Outdoor Environment

Compared with the non-transfer stations in Beijing [30] the correlation between the subway and the outside was the same; i.e., PM10 and PM2.5 were significantly correlated at both transfer stations and non-transfer stations (Table 5). However, the values of the coefficient (R^2) at the transfer stations were higher than at the non-transfer stations. The R^2 was 0.897 for the non-transfer station platforms whereas for the transfer station platforms, the R^2 was 0.907. Compared with the non-transfer stations, the correlation with the outside environment was higher for the transfer stations. This was caused by the structure of the stations because the area of the transfer stations was much larger with more inlets and the flow of passengers was more intensive than in the non-transfer stations. Furthermore, the exchange of air between the outside and the platform was more violent at the transfer stations compared with the non-transfer stations. For future air quality research, more attention should be paid to the outside of the transfer stations than to the non-transfer stations.

Table 5. Comparison of the PM2.5/10 ratio and the R^2 between transfer and non-transfer stations.

		Transfer Stations	Non-Transfer Stations [30]
Ratio (PM2.5/PM10)	Outside	77.65%	79.6%
	Platform	76.28%	68.6%
	Hall	78.1%	61.2%
R^2 (subway and outside)	Platform	0.970	0.907
	Hall	0.968	0.884

5. Limitations and Future Work

As the measurement was very difficult to perform due to the safety of the people, the comfort of the passengers and the requirements of the subway company, the collected data were not large and the number of stations was also limited. For future research, long-term measurements on a higher number of different stations should be performed. For example, peak hour measurements could be conducted and transfer station through nodes could be studied and compared. However, the existing data are statistically significant and show the characteristics of PM2.5 and PM10 concentrations at transfer stations. In this paper, the values of PM2.5 and PM10 were analyzed and a comparison with the non-transfer stations was performed. The method in this paper could be co-opted and the results could be a reference for future, more comprehensive measurement studies.

6. Conclusions

In this paper, the characteristics of PM2.5 and PM10 at transfer stations were studied. The transfer stations that were monitored included two modes. The first was the transfer of passengers through the aisle and the second used one common platform and hall for different lines. The former stations were GM, DWL and SLH, three transfer stations, and the latter was SJZ station. For comparison, the monitoring was conducted under different outside conditions. The monitoring locations included the transfer station platform, the transfer aisles and the hall. In addition to the PM concentration results, the ratio of PM2.5 to PM10 at different locations and correlations with the outside were also analyzed. The main results were as follows:

- The concentration of PM in the aisle was between two platforms at transfer stations. In the transfer station with the same depth of platforms, the concentrations of PM2.5 and PM10 on different lines were the same or similar. The concentrations of PM2.5 and PM10 on the platform in transfer stations were approximately 10 $\mu g/m^3$ lower than in the non-transfer station when the outside PM2.5 was lower than 150 $\mu g/m^3$.
- The ratio of PM2.5 to PM10 at the transfer stations (80% on the platform and 78.1% in the hall) was higher than at the non-transfer stations (68.6% on the platform and 61.2% in the hall), which revealed that the PM10 concentrations differed between the transfer and non-transfer stations.
- The concentration of PM2.5 at the subway stations had a strong correlation with the outside conditions at the transfer stations (R^2 = 0.897), which corresponded with the results for the non-transfer stations. This proved that regardless of the type of subway station, the outside conditions were among the most important factors for the subway environment.

For further studies, it is necessary to measure PM pollution during the peak period and throughout the year in order to reveal the pollution conditions at transfer stations.

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