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# Investigation Of Airborne Particle Concentrations ($Pm_{2.5}$) In The Longest Subway Line In Tehran In Winter

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## Abstract

Metro is considered the most popular method of passenger transportation in many metropolises of the world due to its high capacity of passenger transportation and good safety. So far, many studies have been conducted on particulate matter pollution in closed environments, but few studies have been conducted to measure air pollution in Tehran metro. In this study, the concentration of particulate matter less than 2.5 $\mu g/m^3$ in diameter) $PM_{2.5}$)was measured in the main metro line of Tehran in winter. For a sampling of suspended particles, a portable direct reading device for suspended particles (HAZDUST EPMA5000) was used. To analyze the data, the Analysis of variance( ANOVA) test was used to compare the particle concentrations in different locations of the station and a T-test was used to compare the PM2.5 particle concentrations in the ground level and underground Metro stations. the concentration of $PM_{2.5}$ particles in the platforms, ticket halls, and outside the stations was significantly different ($P < 0.001$). There was a significant difference between the concentration of $PM_{2.5}$ particles in the stations and the daily ticket hall with the underground ($P < 0.018$). the average concentration of airborne particles $PM_{2.5}$ at the stations was 45 $\mu g/m^3$ that more than the Standard limit and the average concentration of $PM_{2.5}$ particles on platforms and ticket sales halls in underground stations is more than on the ground stations.According to the research results, the use of warm ventilation system in winter with a suitable filter is recommended.

**Keywords**

Airborne Particle, $PM_{2.5}$، Subway، Stations.

## Introduction

The metro system is considered as the most popular method of passenger transportation in many metropolitan cities of the world due to its high capacity of passenger transportation, speed and safety[1] However, the high density of particulate matter in the air of underground subway platforms and the negative impact of these particles on human health has attracted much attention[2] If the indoor air quality in the metro system is not managed properly, metro passengers and employees will be exposed to air pollutants in this environment[3] Particle Materials have been selected by the US Environmental Protection Agency as one of the six major pollutant indicators. $PM_{2.5}$ is a particulate matter (PM) less than 2.5 μg/m$^3$, which through inhalation may penetrate the lungs, alveoli, and blood vessels, causing respiratory and cardiovascular disease and even premature death [4,5] In the short exposure term, increasing every 10 g / m3 with a $PM_{2.5}$ concentration increases the mortality from respiratory and cardiovascular diseases by 0.38% [6]. Although it may seem that travelers spend little time in the subway system, however, exposure to high concentrations of PM can adversely affect their health [7]. Also, due to the large number of passengers, contact with air pollution in this place is of great health importance [8]. The results of previous studies in cities with subways have shown that the concentration of air pollutants in underground subways is several times higher than above ground levels [7,9-14] Also, the concentration of airborne particles in the Seoul subway was approximately two or three times greater than the space outside the subway [15-17]. The concentration of airborne particles in Helsinki was three to four times higher than outside [9]. Previous studies showed the concentration of airborne particles in subway stations is higher than the standard[3,18-20]. The subway is a confined space where pollutants from the outside atmosphere and pollutants produced inside (wear of train rails, wheels, brake pads caused by train movement and passenger movement) cause PM suspension in that environment [21]. One of the key factors influencing the concentration of airborne particles is the presence of air conditioning. According to a study by Teresa Moreno et al., Tunnel ventilation plays a very important role in maintaining cleaner air and can reduce the mass of respirable particles (PM) on platforms by more than 50% [22]. In addition to tunnel ventilation, air conditioning inside the train carriages will reduce the exposure of passengers to airborne particles [17,22] According to a study by Weinging Cha et al., In the Stockholm subway, the concentration of airborne particles inside the train is one-fifth that outside the train [23] .The height of the station from the ground is one of the factors affecting the concentration of airborne particles in the subway. According to a study by Yu-Hsiang Cheng et al. In the Taiwan Metro, the concentration of PM inside train carriages in underground tunnels was 3 to 10 times higher than ground level, and the concentration of PM in subway train carriages was not significantly different between ground level and outside air [24] .Tehran metro stations are often very crowded, especially during rush hours due to the high passenger population and the risk of exposure to particulate matter. This study aims to measure the concentration of pm2.5 airborne particles in line one stations as the oldest and the busiest metro line in Tehran was done, so that the results of this study can be used to control the concentration of airborne particles in Tehran metro stations.

## 2. Materials and Methods

In this cross-sectional (descriptive-analytical) study, the concentration of $PM_{2.5}$ suspended particles on station platforms, inside ticket offices, outside stations and inside the Tehran Metro Line 1(one of the busiest metro lines in Tehran) In winter, it was measured for a month between 6 am and 2 pm (one shift). This line has 29 stations with a length of 39 km. And approximately 2 million passengers travel on the platforms of this line daily [25]. Tehran metro ventilation system is cold ventilation, which is used only in spring and summer. In winter, the outside air is distributed in the stations without filtering and proper ventilation. In the warm seasons of the year (summer, spring), the wetting process by water ponds is used to filter the air, but in the cold seasons of the year (autumn, winter), the wetting ponds are deactivated. And only air conditioning is done.

In this study, out of 29 line 1 stations, six stations were randomly selected considering the height from the ground (Table 1). To measure the concentration of $PM_{2.5}$ suspended particles, a portable direct reading suspended particle measuring device called HAZ DUST model 5000 EPMA was used and the particle measurement method was performed according to OSHA CIM instructions. In this method, air is drawn by a vacuum pump through a membrane filter with a diameter of 47 mm and the concentration of dust particles per second is detected. Sampling flow was 4 liters per minute, working temperature (The temperature at which the device can measure correctly) was

-10 to 50 ° C, humidity was 95% and storage temperature( The temperature at which the device must be maintained to remain calibrated )was 20 ° C to 60 ° C. Dust concentrations were immediately calculated and displayed on the LCD –SKC EPMA-5000. At the end of each sampling period, measurement data was transferred to a computer for analysis. Independent variables station position (underground-ground level), particle concentration measurement position (inside the train, on the platform, ticket hall and outside the station) were considered in this research, Also, to measure the temperature and humidity in the stations, fixed systems installed in each station were used. And, to count the passenger population at the time of measurement, we obtained the relevant information from the control room of each station. The data were analyzed with Statistical Package for the Social Sciences (SPSS) software version 22. ANOVA test was used to compare the particle concentrations in two station modes (underground and ground level). To compare the particle concentrations in different measuring positions in each station, ANOVA test was used.

**Figure 1. Comparison of $PM_{2.5}$ particle concentrations in the studied stations**

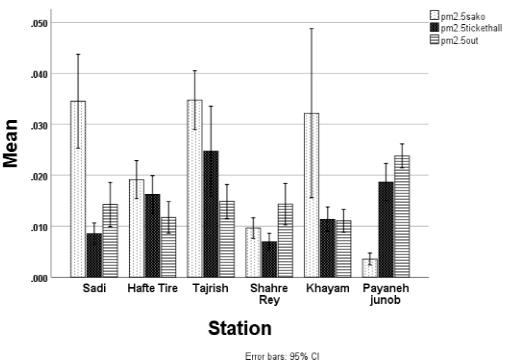


**Table 1, Study stations:**

| Station name | Station mode |
|---|---|
| Tajrish | underground |
| Shohadaye Hafte Tire | underground |
| Sadi | underground |
| Khayam | underground |
| Payaneh Junob | On the ground |
| Shareh rey | On the ground |

## Results and discussions

According to the results of this study, the mean and standard deviation of passenger population in stations was 1292.33 ±1072.64، , the average temperature of stations was 14.73± 2.73 ° C, the average temperature of wagons was 27.34 ±1.34 ° C, the average humidity of stations was 21.64 ±3.13 % and the average humidity of the station was 61.24 ±1. 5 %. Among the studied stations, the highest average concentrations of $PM_{2.5}$ particles in the platform and ticket office of Tajrish station were 0.034 ± 0.016 $mg/m^3$ and 0.025 ± 0.024 $mg/m^3$, respectively (Figure 1). The location of this station (the presence of the shrine of Imam Zadeh Saleh, and Tajrish Bazaar), increases the passenger density, as well as the increase in car traffic in the streets outside the station increases the entry of pollutants into the station. Tehran Metro ventilation system is a cold ventilation system. Ponds are used to trap pollutants and according to observations, there is no filter, so in winter, due to the decrease in temperature, the natural ventilation system is not used and due to the lack of proper ventilation system, it causes outside air to enter. Without filtration, it enters the station, which increases the concentration of particles in the subway environment, and this factor can increase the concentration of particles in Tajrish station. The highest average concentration of $PM_{2.5}$ particles at the subway entrance is related to the south terminal station with 0.023 ±0.006 $mg/m^3$. High density of vehicles (passenger buses and private cars) and high population density (due to the presence of the southern passenger terminal) are the factors affecting the increase of particle concentration outside this station (Table 2). According to Tukey post hoc test, the mean concentration of PM2.5 particles on the platform at Saadi station with Shahreri and the southern terminal, Tajrish with Shahreri and the southern terminal, was significantly different. (P <0.001) The mean concentration of $PM_{2.5}$ particles in the ticket office of Tajrish station was significantly different from Shahreri, Khayyam and Saadi. (001/0> P). The mean concentration of PM2.5 particles at the entrance of the south terminal station was significantly different from other stations. (P <001/0).

**Table2, PM2.5 particle concentrations in the studied stations:**

| Measured station | Mean $PM_{2.5}$ particle concentration (standard deviation ($mg/m^3$) | Maximum particle concentration of $PM_{2.5}$ ($mg/m^3$) | The lowest particle concentration of $PM_{2.5}$ ($mg/m^3$) | P-value |
|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| $PM_{2.5}$ particle concentration on platforms | Sadi | 0.034+_0.026 | 0.098 | 0.001 | < 0.001 |
| | Hafte Tire | 0.019+_0.1 | 0.041 | 0.002 | |
| | Tajrish | 0.034+_0.016 | 0.058 | 0.002 | |
| | Shareh rey | 0.009+_0.005 | 0.018 | 0.002 | |
| | Khayam | 0.032+_0.048 | 0.024 | 0.002 | |
| | Payaneh Junob | 0.003+_0.003 | 0.01 | 0.002 | |
| $PM_{2.5}$ particle concentration in ticket hall | Sadi | 0.008+_0.006 | 0.022 | 0.002 | < 0.001 |
| | Hafte Tire | 0.016+_0.01 | 0.037 | 0.002 | |
| | Tajrish | 0.024+_0.025 | 0.11 | 0.002 | |
| | Shareh rey | 0.006+_0.004 | 0.019 | 0.002 | |
| | Khayam | 0.011+_0.006 | 0.026 | 0.002 | |
| | Payaneh Junob | 0.018+_0.01 | 0.038 | 0.002 | |
| $PM_{2.5}$ particle concentrations Station entrance (outside stations) | Sadi | 0.014+_0.012 | 0.049 | 0.002 | < 0.001 |
| | Hafte Tire | 0.011+_0.009 | 0.026 | 0.002 | |
| | Tajrish | 0.014+_0.009 | 0.033 | 0.002 | |
| | Shareh rey | 0.014+_0.011 | 0.047 | 0.002 | |
| | Khayam | 0.011+_0.006 | 0.025 | 0.002 | |
| | Payaneh Junob | 0.023+_0.006 | 0.038 | 0.002 | |

Also, the concentration of $PM_{2.5}$ particles in both ground and underground states of stations in different measurement positions (on platforms, ticket halls and outside stations) are significantly different (P <0.001). And the total mean concentration of $PM_{2.5}$ particles in different measured positions (on platforms, ticket hall, station entrances, inside passenger cars) were significantly different (P <0.001). In such a way that the concentration of particles on the platforms was significantly higher than the entrance area of the stations and the ticket office. And the lowest concentration of airborne particles was related to the air input the station with the amount (0.015+_0.012). Table 3.

**Table3, average $PM_{2.5}$ particle concentrations in the measured positions:**

| Measurement location | Mean and standard deviation of particle concentration $pm_{2.5}$ (mg / $m^3$) | Lowest particle concentration $pm_{2.5}$ (mg / $m^3$) | Maximum particle concentration $pm_{2.5}$ (mg / $m^3$) | P-value |
|---|---|---|---|---|
| Input stations | 0.015+_0.012 | 0.002 | 0.049 | < 0.001 |
| Stations ticket hall | 0.021+_0.028 | 0.002 | 0.115 | |
| On the platform stations | 0.046+_0.08 | 0.001 | 0.27 | |
| Inside the passenger car | 0.022+_0.014 | 0.002 | 0.047 | |

The results of Figure 2 show the average concentration of $PM_{2.5}$ particles measured in different spatial positions. The highest concentration of $PM_{2.5}$ particles is related to the platforms with a value of 0.046 mg/$m^3$. And the lowest value is related to the input of stations with 0.015 mg/$m^3$.

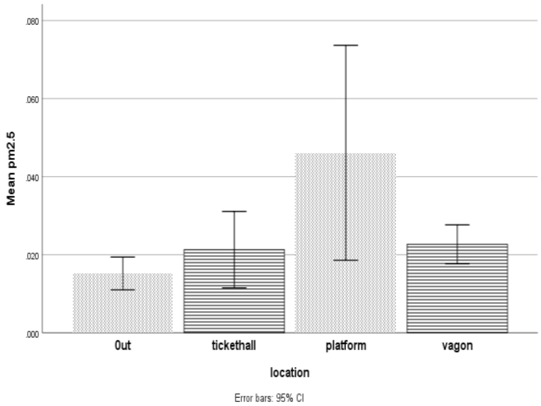


**Figure 2. Comparison of average $PM_{2.5}$ particle concentrations measured at stations**

Based on the results, there was a significant difference between the concentration of $PM_{2.5}$ particles on the platforms, ticket halls and station entrances in the daily stations and the underground stations (P <0.018). The concentration of airborne particles on the platforms was the highest( Figure 2). The average $PM_{2.5}$ particle concentration of underground stations was higher than that of surface stations Table 4). This finding is consistent with the results of previous studies [26-28]. According to Armando Cartenì's study in the Italian metro, the concentration of airborne particles on the platforms of underground stations was higher than the air outside the station, while the concentration of airborne particles on the ground stations was not significantly different from the air outside. On the other hand, leaving the windows open in the underground trains increases the concentration of airborne particles, but in the above-ground stations, the open windows of the train cause clean air to enter the train, which is a natural ventilation.

**Table 4 Comparison of average $PM_{2.5}$ particle concentrations in above-ground-underground stations:**

| Variable | Measuring position | Average concentration measured | P-value |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Mean $PM_{2.5}$ particle concentration on platforms | On the ground | 0.006 | < 0.001 |
| | underground | 0.03 | |
| Average particle concentration in $PM_{2.5}$ ticket sales hall | On the ground | 0.012 | < 0.001 |
| | underground | 0.015 | |
| Mean $PM_{2.5}$ particle concentration at station inputs | On the ground | 0.019 | < 0.001 |
| | underground | 0.012 | |

The concentration of airborne particles and their distribution inside the train is strongly influenced by the environment around the train [29]. Armando Cartenì's study shows that natural ventilation plays an important role in diluting and dispersing particle concentrations in metro stations, especially when air conditioning systems are non-existent or defective. However, at the entrance of the stations, the daily stations have a higher concentration of $PM_{2.5}$ particles. Due to the location of the daily stations (the presence of the shrine of King Abdul Azim and the southern terminal), the traffic of cars and people in the streets around the entrance of the stations is high. Which can be effective as an effective factor in increasing the concentration of $PM_{2.5}$ particles in the input of surface stations compared to underground( Figure 3).

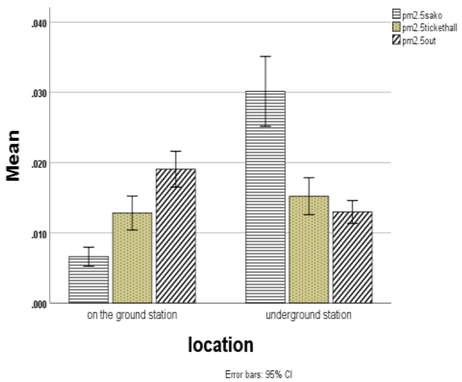


**Figure 3. Comparison of PM2.5 particle concentrations in two underground-terrestrial states**

However, the results of previous studies showed that the concentration of airborne particles in the underground stations of Tehran metro is lower than the values in the metro of other cities in the world. Important factors affect the concentration of particulate matter in underground rail systems around the world, which can vary in length and design of stations and tunnels, system age, wheel materials and braking mechanisms, train speed and frequency, passenger density, ventilation and ventilation systems. Conditionally, the tunnel cleaning frequencies were mentioned [30] (Table 5 . )However, according to the Environmental Protection Agency (EPA), the maximum annual and daily allowable amount of particulate matter is 35 and 15 μg/m3[31] .Accordingly, the average particle concentration in Tehran metro stations is more than twice the daily allowance.

**Table 5 Comparison of particle concentrations in the metro systems of Tehran, Istanbul, London and Italy**

| The variable being measured | Tehran | Istanbul | London | Italy |
|---|---|---|---|---|
| Particle concentration $pm_{2.5}$ | In the present study, the concentration of $pm_{2.5}$ particles was recorded in underground platforms of 45 $\mu g/m^3$. | the concentration of $pm_{2.5}$ particles in underground platforms was recorded at 181.7 $\mu g/m^3$[17]. | the concentration of $pm_{2.5}$ particles in underground platforms was recorded at 88 $\mu g/m^3$[28]. | $Pm_{2.5}$ particle concentrations in underground platforms 60 $\mu g/m^3$[29]. |

## Conclusions

According to the results of this study, the average concentration of $PM_{2.5}$ particles on platforms and ticket sales halls in underground stations is more than on the ground stations. One of the effective factors in increasing the concentration of $PM_{2.5}$ particles in underground stations is the lack of proper ventilation system (not equipped with a filter and cold ventilation) in winter, while in surface stations the ventilation system is natural type which dilutes the pollutant, and reduces the amount of $PM_{2.5}$ particles. Among the stations of line one, Tajrish station had the highest particle concentration. The height from the ground level of Tajrish station is minus 58 meters. In other words, this station is deeper than other stations, which can be one of the factors affecting the increase of $PM_{2.5}$ particle concentration be at this station. In general, the average concentration of airborne particles in the surveyed stations exceeded the standard limit, that increasing the depth of underground stations, lack of proper ventilation system in tunnels and throwing micro-particles from train brakes increase the concentration of $PM_{2.5}$ particles. According to the results, the concentration of $PM_{2.5}$ particles on the station platform is almost twice that inside the train vagon. The presence of a proper ventilation system inside the passenger car that works well in all seasons and the lack of an effective ventilation system, especially in cold seasons at the station can be the main factor in increasing the concentration of airborne particles on the platforms. The need for research on the effect of ventilation systems equipped with appropriate filters and equipping stations with warm ventilation systems in winter, design and application of Platform screen doors( PSD )systems (Platform screen DOORS) or platform separation systems, increasing the frequency of cleaning and washing the tunnel. Isolating workshops for the construction of new subway lines that intersect with the Tehran metro line 1.

**recommendations for the evaluation of airborne particulate matter:**

- Investigation of asbestos and lead in the air of metro stations.
- Investigation of airborne particles in subway stations
- Measurement of suspended particles in the office parts of metro stations
- Measurement of suspended particles at the ventilation outlet of metro stations

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