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Original

Evaluation of Occupational Exposure of Bus Drivers to Road Particulate Matter in Bojnurd, Iran

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Abstract

Background: Drivers of public vehicles, especially in highly polluted and crowded areas, are exposed to high air pollutants, especially particulate matter less than ten microns (PM10). The purpose of this study was to measure and evaluate the level of exposure of city bus drivers to PM10 particles in Bojnurd, Iran. **Methods**: This descriptive-analytical study was conducted in Bojnurd, Iran. A sampling of particulate matter was taken through bus drivers' respiratory area in two routes from the main routes of the city using the Haz-Dust device. This device has been designed and manufactured based on the NIOSH-500 method. Using an impactor 10, the amount of particulate matter less than ten microns was read from the device. Particle sampling was performed in both round-trip buses in three shifts in the morning, noon, and evening for one year. The results of the measurements were statistically analyzed by descriptive statistics and mean statistical indices, independent t-test, Mann-Whitney test and One-way ANOVA test at 95% significance level by SPSS software version 24. **Results**: A total of 420 times, PM10 particles were measured in the drivers' respiratory area. Approximately 21% of the measurement days had a concentration of more than 150 micrograms per cubic meter of air (or μg/m3). Measurements show that among 140 days of measurement, the highest concentration was on May 21 (with 380.66 μg/m3 of air), and the lowest concentration was on August 9 (with 35.33 μg/m3 of air). The average daily exposure of drivers in this one-year was 151.29 μg/m3 of air. **Conclusion**: The exposure of city bus drivers to PM10 particles in Bojnurd was much higher than recommended by the World Health Organization (50 μg/m3 of air) and slightly higher than the US Environmental Protection Agency standard (150 μg/m3 of air), which predisposes them to cardiovascular disease in the future. The active buses on these two routes did not use the air conditioning system, which allowed suspended particles to penetrate the bus from the outside. It is suggested that in order to reduce the drivers' exposure, effective control measures should be adopted and implemented as soon as possible, such as launching an air conditioning system equipped with a HEPA filter.

Keywords: Haz-Dust Device; PM10; Air pollution; Traffic

Introduction

Studies on particulate matter and its effects on public health have shown that particulate matter has detrimental effects on public health, especially among urban populations.[1] The relationship between short-term exposure to air pollution and increased mortality and adverse effects on the pulmonary and cardiovascular systems has been documented in several epidemiological studies.[2-5]

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Studies have shown that active movement techniques, such as cycling, increase respiration, result in more particulate matter entering the lungs.[6] There is also a significant relationship between increasing the concentration of respirable particulate matter in the ambient air and hospitalization rate due to heart and respiratory diseases. Road traffic is the main source of particulate matter (PM) in urban areas.[7] Some studies have shown that PM exposure is higher in passenger cars than in buses.[8] In another study, the duration of cycling caused the cyclist to be more exposed to particulate matter.[9] Vehicle characteristics, differences in the position of the car (or bus) window, ventilation settings, and the seasons and daily periods selected for measuring particulate matter are determinants of particle concentration, which may explain the discrepancies in the findings of various studies.[10] Although most travelers spend only a small portion of their time on the transportation system, high levels of pollution during travel may significantly impact people's exposure.[11]

The amount of air pollution related to traffic varies according to the route, traffic volume, and travel modes. Studies have shown that passengers on diesel buses are three to four times more likely to be exposed to the particulate matter than gas-powered buses.[12] Passengers in cars or vehicles are generally more exposed to traffic-related levels of air pollution than those who choose almost all alternative modes, including walking, cycling, buses, subways, and trains.[13-15] Especially in urban areas, traffic is the main source of particles that affect passengers and drivers. Direct exposure to airborne particles varies greatly depending on the intensity of the traffic, the type of transport, the type of vehicle, and the age and behavior of the driver in traffic. A study in London found that spending 2 hours on the subway would increase a person's 24-hour exposure by 17 micrograms per cubic meter of air.[16] Many epidemiological studies have assumed that concentrations of environmental pollutants are monitored regularly, and some studies have concluded that the relationship between exposure and concentration can be predicted at different locations in a city.[17]

The reasons for this discrepancy are varied in the findings, including local variables such as vehicle fleet and traffic regulation, environmental pollution, and environmental factors, which are some of the reasons why some studies suggest that vehicle drivers may be at risk.[18,19] In a study conducted by Mohammadian et al. in 2007 in Sari, it was found that the concentration of PM10 particles varies at different times of the day, so that in the afternoon, the concentration of these particles is significantly higher than in the morning. They also concluded that the concentration of these particles is higher in busy routes.[۲۰] The increase in the number of cars in Bojnurd and the lack of change in the number and extent of roads, especially in the central part of the city, has caused heavy traffic during the hours of the day, also, due to the age of vehicles and city buses that still use diesel as fuel, it is one of the causes of particulate pollution in the city air.[21] The presence of inhalable particles from traffic threatens the health of people in the community, especially city bus drivers who are exposed to direct inhalation of these particles due to their job.

Given that people in the community, especially employees working in the urban transport sector in our country, spend a significant part of their time in vehicles, policies should be adopted, which aim to limit traffic volume by reducing private cars and promoting public transportation systems. Although public transportation systems are effective for environmental sustainability, public health consequences are equally important and must be properly considered, and appropriate measures must be considered. Dependence on public transportation has led to bus drivers' exposure to air pollutants, especially inhalable particulate matter, which is a type of continuous exposure. Previous studies in this area have not paid attention to the drivers and spaces of

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city buses, and also most of the measurements of particulate matter have been done in a short period. According to the necessary studies, particulate matter was measured in three shifts in all months for one year in this study. Considering the few studies that have been done in the field of measuring and evaluating the concentration of particulate matter in Bojnurd and also many harmful effects that these particles have on the human respiratory system, the purpose of this study was to measure and evaluate the exposure level of city bus drivers with PM10 particles in Bojnurd.

Methods

This descriptive-analytical study was conducted to investigate and evaluate bus drivers' exposure to inhalable particles (PM10) and investigate the differences in concentration and number of particles for different times and seasons in Bojnurd. Since the bus organization buses provide services to the citizens in 13 city lines and the number of active buses in Bojnurd is 53, and 4 buses are ready to serve in each route, information about bus routes was received from Bojnurd and suburbs bus driving organization.

Since measuring particles in the respiratory area of all drivers for a year, in the thirteen routes of Bojnurd was practically expensive and almost impossible, so sampling in two routes of the main routes of the city (Amusement park - airport, airport - Amusement park and Javadiyeh-Malkesh, Malekesh-Javadiyeh) took place. From these 13 lines, two lines were randomly selected. Particle sampling was performed in the round trip of buses in three shifts in the morning, noon and evening, and almost simultaneously with the start of work and the closure of schools, in a rotating manner in all months of the year. Sampling was performed from 7 to 10 in the morning, 11 to 14 at noon and 4 to 7 in the evening. In this study, a direct reading device called Haz-Dust was used to measure particulate matter. The device is designed based on the NIOSH-500 method and can be used. Thus, all indicators, including the time-weighted average exposure, were read from the device.

This device is called Haz-dust EPAM5000, made by Environmental devices corporation in the United States of America. The detectable range for this device is 0.001 to 200 mg/m3 of air. According to the specified sample size and number of repetitions in the measurement, our sampling set was fixed in the driver's respiratory area for sampling, using the device accessories (Impactor No.10), and a Teflon filter of contaminants was read from the device. The required flow in the sampling process was set at 2 liters per minute, and the sampling pump was calibrated before sampling using a soap bubble flowmeter. Although the authors were going to cover all the days of the year, they could not take samples in 76 days because of holidays. In order to determin the exact sample size, bellow formula (1) was apllied:

$$n = \frac{N \times Z^2_{\alpha/2} \times pq}{N \times d^2 + Z^2_{\alpha/2} \times pq} \qquad (1)$$

In this formula, N is the total statistical population, $Z_{\alpha/2}$ is reliability coefficient, p is the probability of having an attribute in the community, q is the probability of not having an attribute in the community and d is the sampling accuracy. In this study N was 840 (280 days and each day three times sampling, morning, noon, and after noon), $Z_{\alpha/2}$ was 1.96, p and q were 0.5, and d was 0.05 based on the previous studies. Therefore, the sample size was quantified to be 264, besides, to strengthen the accuracy of the results 420 samples were taken. Out of the remaining 280 days, only 140 days were considered as one day in between, to be sampled. The results of measurements were statistically analyzed using descriptive statistics and statistical indicators including mean, minimum, maximum, and standard deviation, using independent t-test, Mann-Whitney test and One-way ANOVA test by SPSS statistical software version 24 at a significant level 95%.

Results

In this study, a total of 140 times in the morning, 140 times in the afternoon, and 140 times in the evening, the concentration of particulate matter less than 10 microns was read from the device. Then, for the daily exposure of drivers, through time weight averaging (TWA), we reached a concentration in micrograms per cubic meter of air. The average daily exposure of drivers to particulate matter is shown in (Figure 1). Daily exposure of up to 150 µg/m3 of air to PM10 particles is permitted according to the US Environmental Protection Agency (EPA) standard[22] and is shown in green, also the amount of above this limit is considered unauthorized and are shown in red. Approximately 21% of the measured days (29 days out of 140 days) in the morning, noon, and evening had a concentration of more than 150 µg/m3 of air.

Measurements show that among 140 days of measurement, May 21 (with 380.66 µg/m3 of air) had the highest concentration and the lowest concentration on August 9 (with 35.33 µg/m3 of air). The average daily exposure of drivers during this one-year period was 151.29 µg/m3 of air. The results of the Kolmogorov-Smirnov test showed that all information followed the normal distribution (*P*-value = 0.835) while the information on the two round-trip routes did not follow the normal distribution (*P*-value = 0.006). One-way ANOVA test showed significant differences between the mean monthly exposure to PM10 particles during the study period (*P*-value = 0.031). As shown in Figure 2, the highest concentration is related to June with an average of 240.16 µg/m3 of air, and the lowest concentration is related to July with an average of 65.6 µg/m3 of air. The average exposure of drivers to particulate matter less than 10 microns in different seasons of the year is given in Table 1. As can be seen, spring has the highest level of pollution with an average of 199.27 µg/m3 of air, while summer, with an average concentration of 79.19 µg/m3 of air, has been the lowest and cleanest season of the year.

Autumn and winter seasons with average concentrations of 176.93 and 155.10 had a concentration of more than 150 µg/m3 of air. At the 95% confidence level, the One-way ANOVA test showed that there was no significant difference between the measured values in the morning, noon, and afternoon (*P*-value = 0.761). Independent t-test also showed that there is a significant difference between the mean level of contamination in the two routes (*P*-value = 0.02), the Malekesh-Javadiyeh route with a concentration level of 173 µg/m3 of air had a higher level of pollution than the airport-amusement route with an average pollution level of 129.5 µg/m3 of air. Also, using Mann-Whitney statistical test, it was observed that there was no significant difference in the mean concentration of PM10 particles in the round trip route at all times of the day in the two routes studied.

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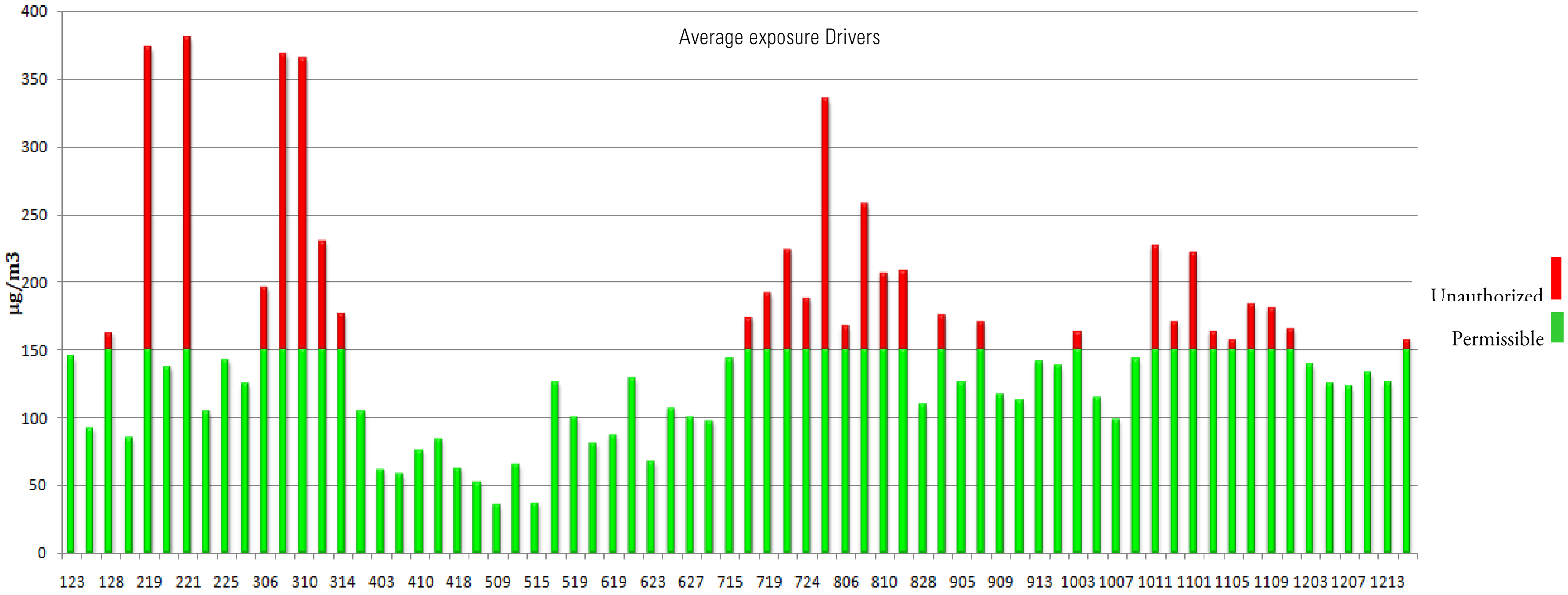

Figure 1. Average daily exposure of drivers PM10 μg/m^3 of air

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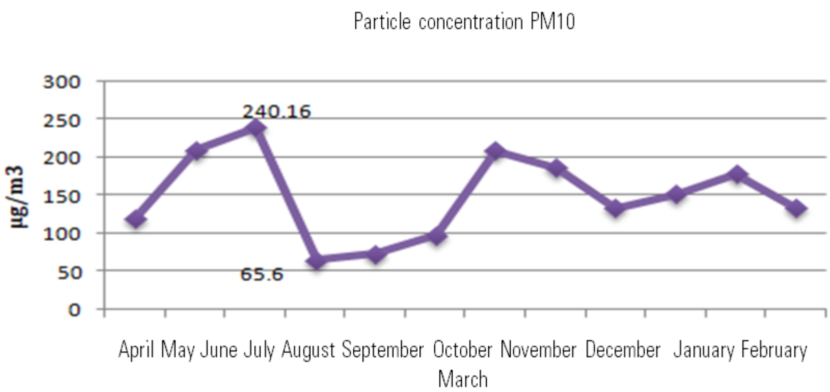

Figure 2. Average monthly concentration of PM10 µg/m3 of air

Table 1. Average exposure to PM10 particles in different seasons of the year for bus drivers (µg/m^3)

seasons	N	Minimum	Maximum	Mean	Std. Deviation
Spring	16	84.66	380.67	199.2700	109.69279
Summer	18	35.33	129.17	79.1944	27.15354
autumn	18	109.50	335.17	176.9259	56.94124
winter	18	98.50	227.00	155.1019	34.53951

Discussion

In this study, the average daily concentration of PM10 particles over a one-year period was higher than recommended by the US Environmental Protection Agency (EPA). This organization has stated in its standard that the daily concentration of PM10 particles should not exceed 150 µg/m3 of air more than once in a three-year period. The one-year average concentration of PM10 particles in this study was 151.29 µg/m3 of air, which is close to other researchers' studies.[23] On the other hand, the World Health Organization (WHO) has stated that the permissible concentration of exposure to PM10 particles in a day is equal to 50 micrograms per cubic meter of air, which this amount is much higher for bus drivers in the city of Bojnurd, which makes them susceptible to cardiovascular disease in the future 1. A study in Bangkok also showed that drivers' exposure to particulate matter was higher than allowed, which is consistent with the findings of this study.[24]

High concentrations of PM10 in the spring can be attributed to the suspension of eroded particles on the roads, which is due to the fact that traffic increases in the spring, as well as during the winter due to snow and rain on the road surface are eroded and ready to be suspended,[25] which this situation in our study can be understood from the high concentration of particles in May. In a Swedish study, researchers attributed almost 90 percent of the region's PM10 particles to the erosion of road surfaces in winter.[26] Buses in Bojnurd did not use air conditioning, and drivers were more exposed to particulate matter. The high concentration of PM10 particles in this study was in line with the findings of other studies in which buses did not use air conditioning. In a study by Praml and Schierl et al. (2000), PM10 concentrations were reported to be between 110 and 165 µg/m3 of air.[23] Also, a study by Chan et al. (2002) in China reported a particle density of 203 µg/m3 of air.[27] However, in the buses that had air conditioning and the bus's windows were not open, a much lower concentration was reported.

A study in China examined the difference between the concentration of particulate matter in buses with and without air conditioning. The findings of this study prove that the concentration of particulate matter is strongly related to the air conditioning system so that in vehicles without air conditioning, particle density is equal to 147, and in vehicles, with air conditioning system, this number is equal to 67 µg/m3

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of air.[28] The results of this study showed that the concentration of particulate matter is higher in autumn, winter, and spring than in summer. One of the possible reasons for the high concentration of particulate matter in winter can be the inversion and stability of the air, which various studies have shown the effect of temperature inversion on the density of air pollutants.[29] In a similar study conducted in Sari, the findings showed that the particle density is higher in autumn and winter than in spring and summer, which is almost consistent with the findings of this study. In a study conducted in Sari by Mohammadian et al., they measured suspended particles for 30 days a year and stated that the average exposure of bus drivers was 180 μg/m3 of air, which is slightly more than (151/3 μg/m3 of air) the findings of our study. Also, in a study by Mohammadian et al., the buses they studied did not use air conditioning.[30] This difference in the concentration of particles in the two studies can be attributed to this issue, which in the study of Mohammadian particle concentration was measured in a short period of 30 days, while in our study, sampling for one year in all months Has been done.

The findings of the present study showed that there was no significant difference between particle density in the morning, noon, and afternoon, while in the study by Mohammadian et al., it is stated that exposure to PM10 in heavy traffic during the evening was significantly higher than the measured values in the morning and afternoon. This difference can be explained by the fact that Sari is a tourist city with a larger population, which makes the streets more crowded and more traffic during the evening, which in turn increases the density of airborne particles.

Conclusion

This study was performed to measure drivers' exposure to PM10 in Bojnurd, Iran. The findings showed that bus drivers experience higher concentrations than reported by the World Health Organization, which requires further investigation into the factors influencing this issue in the future. Factors such as the type of bus, the type of fuel, and the ventilation system can be effective in creating this high particle density. As a result, policymakers need to plan well to take effective action to reduce driver exposure. Previous studies have shown that there is a significant relationship between exposure to high concentrations of PM10 particles, both daily and over time, with increased mortality or morbidity. Conversely, when the concentration of small particles decreases, their mortality also decreases, assuming that the other factors are the same. This allows policymakers to predict population health improvements if airborne particulate matter levels decline. The present study showed that some control measures such as improving traffic management, better vehicle maintenance, complying with international standards in the spread of pollution can be very effective in reducing drivers' exposure to particulate matter. Since PM2.5 particles are very effective in causing cardiovascular disease, measuring these particles and examining more factors that are effective for health is suggested in future studies.

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