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# NANOPARTICLES SIZE DISTRIBUTION IN THE EXHAUST EMISSIONS OF DIESEL AND CNG BUSES

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**ABSTRACT:**

**Introduction:** Motor vehicles are the most important sources of gaseous and particulate matter emission in urban areas with the serious health effects which cause the respiratory and cardiovascular diseases and mortality. Motor vehicles emit a broad range of PM from 0.003 to 10 µm.

**Materials and methods:** The exhaust emission of BRT and diesel buses was samples by portable environmental dust monitor, model EDM 107 during summer and winter 2016. ANOVA was applied at a significant level ($P_{value} < 0.5$) to compare the amount of emitted particles in each season.

**Results:** The lowest concentration of emission was seen in BRT buses and the average number of particles in every liter of exhaust sample was 776330 ± 40428. The amount of emission from BRT buses in winter was 166217 ± 971870. There is a significant difference between total emissions of nanoparticles releasing by diesel and BRT buses in each season, but there isn't any significant difference between the emissions of nanoparticles releasing by diesel buses in summer and winter.

**Conclusions:** There was the high emission of particles emitted by diesel buses in both seasons. Since the impacts of particulate matters on health should be considered in Tehran, planning the best locations for bus terminals and also monitoring these places continuously are recommended.

## INTRODUCTION

Because city buses have the capacity to transport hundreds of passengers, it is important to minimize the traffic congestion and air pollution in urban areas. However, the diesel engines typically used in city buses generate and emit ultrafine particle emissions that are known as the most harmful air pollutants for human health [1, 2]. Regarding the importance of particulate matters in air pollution, current air quality legislation in the European Union focuses on the regulation of fine particulate matters less than 2.5 µm ($PM_{2.5}$) and total PM up to 10 mm ($PM_{10}$) [3, 4]. In recent years, aerosols have been studied widely because they play an important role on climate regulation and human health so that particle number size distribution (PNSD) is recognized as a key metric in regional lung deposition. In atmospheric environments, the PNSD is ideally characterized by a multi-lognormal structure, usually based on four main modes: the nucleation mode (Dp < 30

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nm), the aitken mode (30 nm < Dp < 100 nm), the accumulation mode (100 nm < Dp < 1 µm) and the coarse mode (Dp > 1 µm) [5, 6]. The particulate matter emission from vehicular exhaust represents a mixture of fine, ultrafine, and nanoparticles. Toxicologists define ultrafine particle as those with sizes less than100 nm, fine particles as those less than1000 nm and coarse particles as those above 1000 nm [7, 8]. Solid particles occur in IC- engine exhaust at concentrations of $10^{7}$ – $10^{8}$ particles / $cm^3$ [9]. Diesel exhaust particles (DEPs)(Jung, 2017 #5) have been associated with adverse health effects, including cardiovascular disease, lung cancers, and asthma [10, 11] City buses transit in urban areas more than the other heavy - duty vehicles, so many municipalities, including Los Angeles, Sacramento, Cleveland, and Atlanta, have recently modified the fleets to compressed natural gas (CNG) as the "clean" alternative fuel for conventional uncontrolled diesel vehicles in order to compliance with the air quality regulations about decreasing particulate matters [12-14]. The concentration of particles emitted by natural gas engines is not necessarily low compared to diesel engines [12, 15]. In recent years, compressed natural gas (CNG), as a cleaner alternative vehicular fuel, has been replaced with diesel. Vehicles with CNG fuel doesn't emit visible particulate matter (PM) or black soot from the exhaust and it has been seen over 90 % lower PM emission compared to diesel [16]. However, the median particle number emission from CNG buses was 6 times higher than the diesel buses, and the particles from the CNG buses were mainly in the nanoparticle size range [17] . According to a study it was performed the comparative analysis of emission and performance parameters for gasoline and CNG in a 1.5 L, 4 - cylinder SI engine [18]. In another study, it was reported that a large fraction of particulates from CNG buses contains traces of oil leak. This showed that lubricating oil and wear debris are major fraction of particulates from CNG vehicles [13]. Recent studies have characterized the nanoparticle size distributions from diesel and CNG engines buses.

## MATERIALS AND METHODS

In this descriptive cross-sectional analysis, the particles were measured by portable environmental dust monitor, model EDM 107. The particle size distribution was calculated in the range of 300 to 1000 nm. In order to prevent the interference of temperature in number of particles exhausted from cars, this study was conducted in two seasons, summer and winter 2016, twice monthly. In the other word, total 6 times measurement for the warm season and total 6 times measurement for the cold season were performed biweekly, during 10 am to 1 pm. Due to the limitations of measurement, duration for every measurement was 5 min. According to the time interval of the device, every 6 seconds the number of particles per liter of air measured. Measuring the particles in the above mentioned range was conducted for diesel buses exhaust in Azadi terminal and CNG buses in the city.

Sampling point for the number of particles was next to the exhaust of buses and the exhaust gas was completely in contact with the sensor of dust monitor sampling device. Then data was collected and distribution particles was calculated. The average of measurements was analyzed by R software with the normality test. Then analysis of variance was used for the distribution of particles for every seasons in order to compare together.

In this study, measuring of nanoparticles were in stationary condition, so that the buses were waiting to accept passengers in terminal have not been turn off from the beginning of the work day.

## RESULTS AND DISCUSSION

The number of particles emitted from the exhaust of diesel and CNG buses has been shown in Fig. 1. The number of nanoparticles per liter of the exhaust air from diesel and BRT buses were measured in warm and cold seasons.

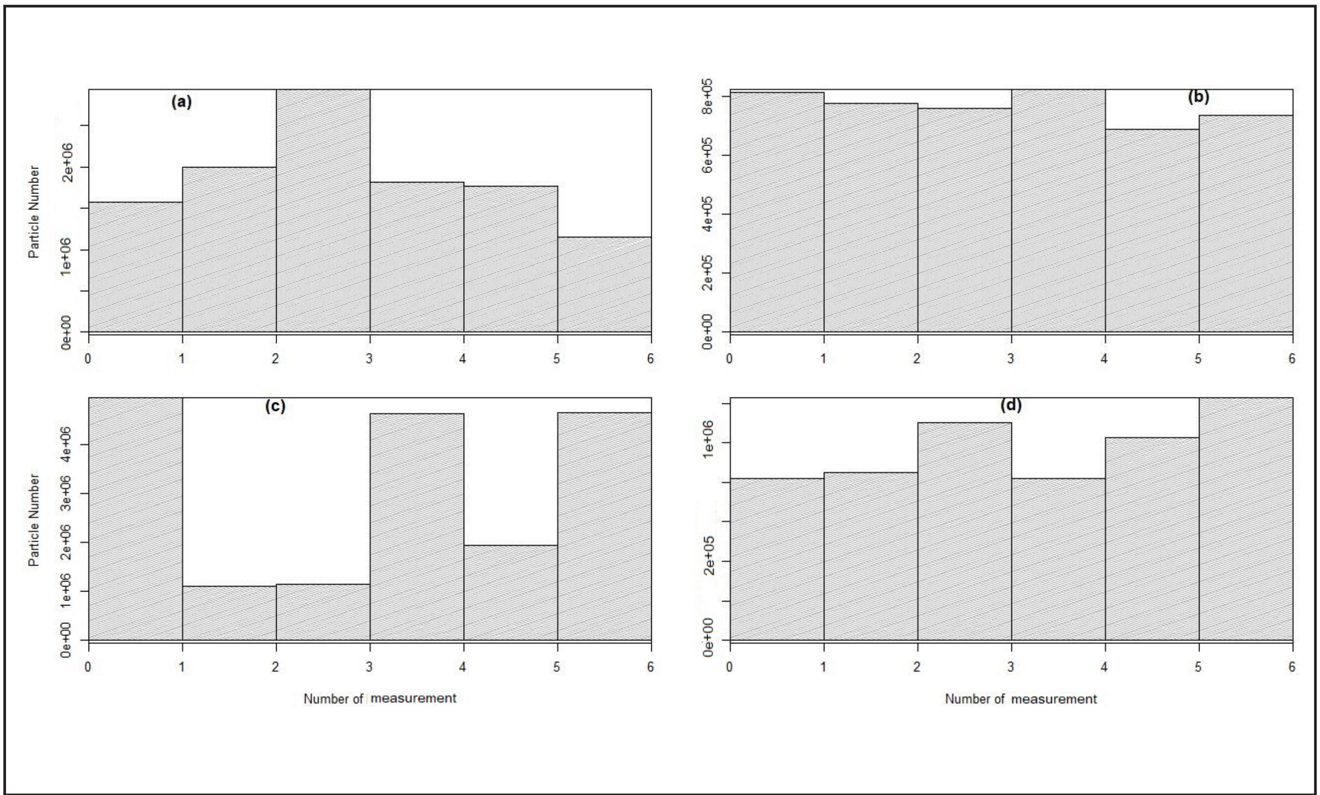


Fig. 1. Histogram of nanoparticles in the range of 300-1000 nm in warm and cold season, (a) exhaust nanoparticles from diesel buses in the warm season, (b) exhaust nanoparticles from CNG buses in the warm season, (c) exhaust nanoparticles from diesel buses in the cold season, (D) exhaust nanoparticles from CNG buses in the cold season

With respect to the difference in type of fuel, the number of nanoparticles emitted by diesel buses is more than nanoparticles emitted by CNG buses for both summer and winter, as shown in the diagram.

The normality of data should be determinated in order to choose the appropriate statistical analyzes. After measurement, the normality of data was checked by the normality graph. Considering the measured particles were in the range of nanoparticles, data were calculated logarithmically in order to clarify the interpretation. Fig. 2 shows the distribution of data in terms of the normality.

As seen in Fig. 2, the distribution of data was normal, therefore the parametric tests were applied for interpretation. Regarding the log- normal distribution, the parametric ANOVA was used. The box plot was used to compare the number of particles emitted by buses in summer and winter ( Fig. 3).

In order to compare the number of emitted particles by diesel and BRT buses in winter and summer, the box plot was used as can be seen in Fig. 3. This graph shows the number of particles emitted by buses in each season. The lowest concentration of emission belongs to BRT buses with the average number of particles equal to 776330±40428 / $L_{exhaust\ air}$. The amount of emission from BRT buses in winter was 166217 ± 971870. The highest emission of diesel buses in idle mode was attributed to diesel buses which travel between cities with the highest particle emission per liter of exhaust air in winter (1831009 ± 3056733). Diesel buses emissions were lower in summer compared to winter equal to 1722848±461051 / $L_{exhaust\ air}$. ANOVA was used in a significant level ($P_{value}$ <

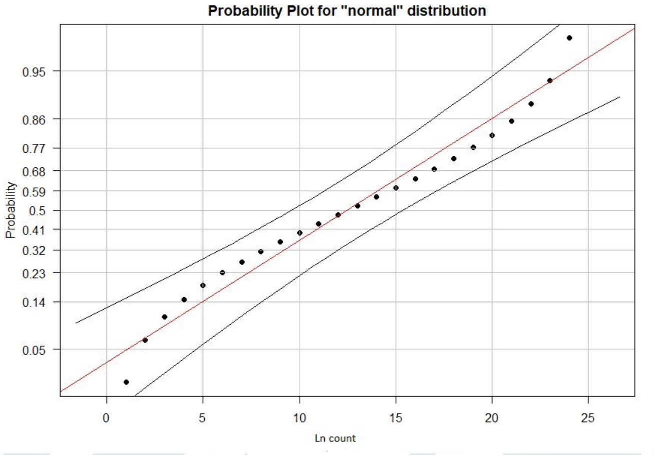

Fig. 2. The normal distribution of data

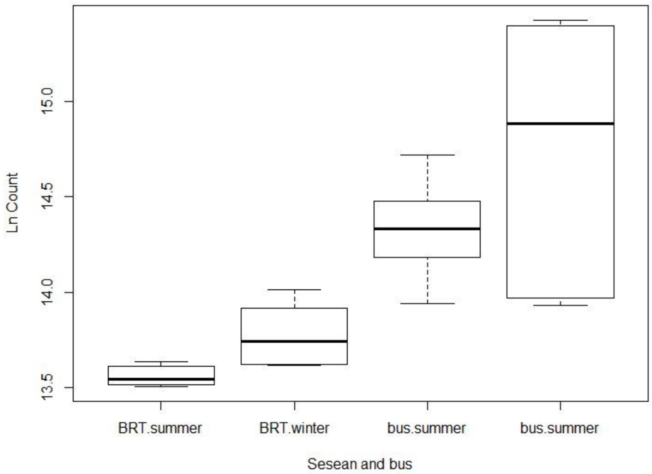

Fig. 3. Logarithmic box plot of the number of particles emitted by BRT and diesel buses in summer and winter

Table 1. Comparing the results of Turkey HSD post - test based on the type of bus and season

| Season- Bus | diff | lwr | upr | p adj* |
|---|---|---|---|---|
| Bus (Summer) –BRT (Summer) | 13.5 | 7.851817 | 19.14818 | 9.2E-06 |
| BRT(Winter)- BRT (Summer) | 5.833333 | 0.185151 | 11.48152 | 0.041392 |
| Bus(Winter)- BRT (Summer) | 15.33333 | 9.685151 | 20.98152 | 1.4E-06 |
| BRT(Winter)- Bus (Summer) | -7.66667 | -13.3148 | -2.01848 | 0.005697 |
| Bus(Winter)- Bus (Summer) | 1.833333 | -3.81485 | 7.481516 | 0.800538 |
| Bus(Winter)- BRT(Winter) | 9.5 | 3.851817 | 15.14818 | 0.00072 |

*($P < 0.05$) values were based on ANOVA analysis

0.5) to compare the amount of particles emitted by BRT and diesel buses in each season as can be seen in Table 1. After ANOVA, the $P_{value}$ calculated lower than the significance level. It means there is a difference in the mean of data. So The Tukey HSD post - test is required to determine it. The results of Tukey test are shown in Table 1 and Fig. 4.

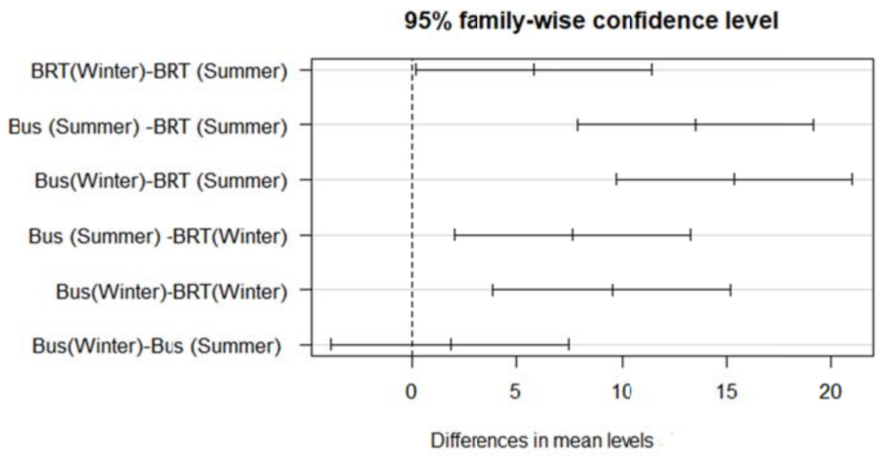


Fig. 4. Tukey HSD post - test plot

As shown in Table 1 and Fig. 4, there are some differences between the number of particles emitted by diesels and BRT in summer and winter, which are as follows. As can be seen in Fig. 3, there is a significant difference between total emissions of diesel and BRT buses in summer ($P < 0.05$); diesel buses in winter and BRT buses in summer ($P < 0.05$); diesel and BRT buses in winter ($P < 0.05$); BRT buses in winter and summer ($P < 0.05$); and BRT buses in winter and summer ($P < 0.05$). There is not significant difference between diesel buses in winter and summer ($P> 0.05$). In this figure, there is a significant mean difference in the lines that do not pass the zero point. But those which pass this line don't have significant mean differences.

According to the results of Table 1 and Fig. 4, it can be concluded that there isn't any significantly difference in the particle emissions of diesel buses in different seasons so that these emissions are always high. Given that the measurements conducted while the bus engine was sufficiently heated, difference in season didn't effect significantly on particle emissions. However, if measurement conducted at the the starting, the particle emissions would be much higher. There is also a significant difference between the amount of particulate matters emitted by diesel and BRT buses in each season which represents more emission from diesel buses. There is a significant difference in the emissions of BRT buses in cold and warm seasons , so that the amount of emissions in the winter is higher than summer due to the better evaporation rate in the summer. It should be noted that particle sizes are usually less than 10 nm for CNG buses and a range of 1-5 nm should be considered more [15]. In this study only particles between 300 - 1000 nm were measured.

## CONCLUSIONS

In this study the concentration of particles emitted by diesel buses and BRT buses (CNG buses) were measured using a dust monitor in both summer and winter.

Some factors, such as the bus model, repairing, fuel consumption, regular maintenance of buses, and the frequency of use, affect the amount of pollutants emission. Due to limitations in the measurement, only one bus was measured at each turn. The results of this study show the high emission of particles from diesel buses in each season. Since the impacts of particulate matters on health should be considered in Tehran, planning the best locations for bus terminals and also monitoring these places continuously are recommended.

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## COMPETING INTERESTS

Herby the authors declare no conflict of interests.

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## ETHICAL CONSIDERATIONS

Authors have completely considered all ethical issues.

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