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Investigation of the concentration of particles generated by public transport gas (CNG) buses

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Abstract

The sustainable development of public transport is inseparable from its key elements, transport. In recent years, reflections on green public transport have been steadily intensifying and setting new guidelines for its development focused on the environment. Gas-powered, more environmentally friendly diesel buses are used for this purpose. Part of such a transport fleet in Vilnius consists of such buses. Pollution from mobile sources is predominant in cities, so particulate matter from different gas buses (powered by CNG) was identified in this study. In this study, particle concentration measurements were performed, in which the dependence of the particle concentration on the mileage of the buses was determined.

Keywords

Sustainability of public transport, gas buses, particulate pollution

1. Introduction

Since industrial revolution urbanization process started to spread all over the world. Nowadays, it has almost reached the point when disadvantages exceed benefits. Overflow of citizens in cities is the main problem which causes higher level of air, particle, noise and light pollution (Dyr et al., 2019). All these and other reasons may do harm to environment and human health(C. Wang et al., 2015), (Tong et al., 2000), (Smieszek et al., 2019).

Exhaust gasses from motor vehicles are the primary origin of air pollutant emissions (Chernyshev et al., 2019)(Chernyshev et al., 2018). Various harmful substance proportions in emitted gasses varies depending on vehicle type, it's age and fuel type which is being used. However, the scale of air pollution mostly depends on number of vehicles that are in traffic. Public transport serves the purpose of optimizing traffic. In majority of busses heavy-duty engines are used (Yu & Li, 2014)(Chao Wang et al., 2018). Although, other emission standards apply with higher emission factors and pollution levels (Shan et al., 2019), air pollution decreases when public transport is being involved in daily citizen trips (Chao Wang et al., 2018).

To determine how air pollution changes and how emissions depend on used fuel type and on technical condition of vehicle several research was made. Multiple studies show that vehicles produce less greenhouse gasses and toxic materials when is fueled with natural gas than vehicles fueled with diesel. In China, if diesel driven buses are switched to gas-hybrid electric buses, the emissions will be reduced by approx. 75 % (Chao Wang et al., 2020). Due to budget limitations and natural gas

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supply infrastructure, this goal can be achieved in steps and the percentage of hybrid electric buses should reach 50 % in 2030(Zhang et al., 2014). Another study was conducted in British Columbia, Canada (Pourahmadiyan et al., 2021). It showed that compressed natural gas (CNG) vehicles contributes to global warming 60 % less than diesel driven ones. According to dynamic simulation results liquified natural gas (LNG) driven buses emits 5.9 % less greenhouse gases than diesel in driving phase. Less optimistic study conducted in Imphal City, India showed that CO and C_xH_y emissions are at higher level when using light-duty diesel engines and that in heavy-duty diesel engine vehicles these factors are in alarmingly high levels (Singh et al., 2022). Other study emphasizes that not all buses' emissions are meeting the standard norms and that best results were revealed when testing CNG vehicles, that tend to have lower CO_2 emissions in India(Cooper et al., 2014). Same study discusses the best fuel type for public buses in Brazil: lowest emissions were conducted by buses fueled by biodiesel and CNG. One more study conducted in Madrid, Spain compared CNG and diesel fueled buses' emissions (Gómez et al., 2021). With respect to distance and average emitted material quantity results showed that heavy-duty Euro VI-C buses emissions are comparable and practically the same.

It is becoming very important to identify the amount of particulate matter emitted by CNG-powered buses, as the level of PM concentration is highly dependent on the final products of combustion of complex hydrocarbons (diesel). When it comes to CNG fuels, their main component is methane, so PM levels are low. In the present work, studies of the concentration of aerosol particles were performed in order to identify the concentration of particles in the operation of different gas buses operating in the field of transportation of urban residents. Such an objective is to ensure the concept of sustainability in the field of public transport, where, according to the EU White Paper on Transport, the key aspects are focused on the sustainable development of public transport. This is achieved by improving ambient air quality by reducing pollution from mobile sources.

2. Methodology

The particles concentration in the exhaust gas was determined using a P-Trak Ultrafine Particle Caunter 8525 particulate meter (Figure 1). The technical specifications of this device are given in Table1.

Figure 1. Particulate Meter P-Trak Ultrafine Particle Caunter 8525 (1 - On / Off button; 2 - Isopropyl alcohol cartridge; 3 - Data connector; 4 - Power connector; 5 - Headphone connector; 6 - Telescopic probe hose)

Table 1. Particle meter technical specification

Concentration range	**0 – 500 000 part./cm^3**
Aerodynamic particle diameter range	0,02-1 µm
Temperature range	-40 – 70 °C
Intake air flow: **-flow of one sample** **-total sample flow**	100 cm^3/min 700 cm^3/min
Type of alcohol used in the appliance	100% isoprophil

This device is designed to measure particles with an aerodynamic diameter of 0.02 - 1µm. As shown in Fig. 1, it consists of a housing with a pump already installed, data processing equipment, a cassette containing isopropyl alcohol and a telescopic probe to be connected. (TSI Incorporated 2019). Table 1 also states that the P-Trak Ultrajine Particle Counter 8525 has a measuring range of up to 500,000 particles per cubic centimeter and an ambient temperature of -40 ° C to 70 ° C.

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In order to isolate the measuring medium from the ambient air, in which particles are also detected, and to ensure the most accurate possible values of the particles, the telescopic probe of the meter was inserted into the exhaust pipe extension (hose) and fixed in the same position as shown in Figure 2:

Figure 2. Particulate concentration measurement

Measurements were performed 5 times for each vehicle. One measurement took about 20-25 seconds. During this time, the instantaneous particle concentration recorded by the device and displayed on its screen usually became constant. For the analysis of the obtained results, the averages of the particle concentration values were used, which were calculated by the device after each measurement and stored in the internal memory of the device.

6 units were taken for research. Vehicles of class M3 of the same make and type. All of these buses met EURO 6 emission standards. Their data are presented in Table 2.

Table 2. Class M3 test vehicles

Designation	Make	Mileage, km	Engine type	Engine power kW	Year of manufacture	Emission standard
A.	Solaris Urbino 12 CNG	778967	Cummins L9NE6E320	235	2018	EURO 6
B.	Solaris Urbino 12 CNG	999236	Cummins L9NE6E320	235	2018	EURO 6
C.	Solaris Urbino 12 CNG	821635	Cummins L9NE6E320	235	2018	EURO 6
D.	Solaris Urbino 12 CNG	1145212	Cummins L9NE6E320	235	2018	EURO 6
E.	Solaris Urbino 12 CNG	843257	Cummins L9NE6E320	235	2018	EURO 6
F.	Solaris Urbino 12 CNG	986578	Cummins L9NE6E320	235	2018	EURO 6

3. Results

The obtained research results showed (Fig. 3) that a certain grouping of particle concentration according to the number of buses was observed. The concentrations of A, C and E particles in the study buses were very similar and did not differ by more than 10%. The quantile field of the results of these buses was small and reached up to 10 parts. / cm^3. This result is very reliable, as the dispersion of the particle concentration was up to 2% of the value of the results. It can be argued that the concentration of particles generated by these buses is minimal and particulate pollution is minimal. In the case of buses B and F, it was observed that although the average of the results was very similar to the aforementioned buses A, C and E, the field of quantiles of the results was significantly wider and accounted for up to 12% of the value of the results. Such differences can be explained by the more intensive operation of buses, during which the concentration of particles generated due to the natural wear of bus units' increases.

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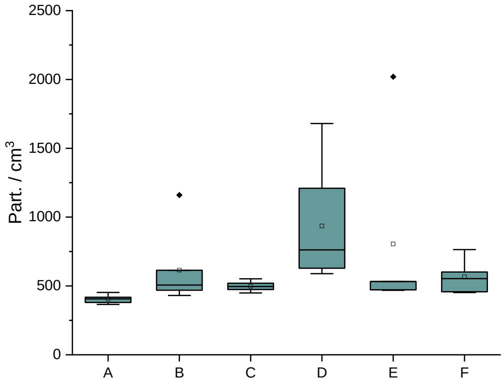
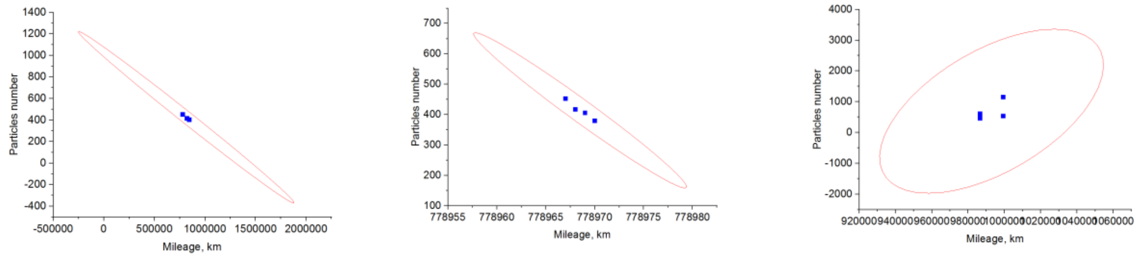


Figure 3. Particulate concentration measurement results

This trend is clearly illustrated by the D bus. Its operating frequency is the highest among all buses tested (Table 2), as shown by the value of particle concentration. It is distinguished not only by the value of its results (it is almost twice as high as the bus studied earlier), but also by the very large (up to 96%) dispersion of the particle concentration from the value of the results. This already indicates uneven engine performance and can be identified as an imminent need for engine repair. If we examine the scattering of the random measured values, it is noticeable to the previously stated dependence that Bus D had an instantaneous particle concentration up to 1720 part. / cm^3.

It is observed that such dispersion of the amount of particles was caused by the technical condition of the buses and could be used as an indicator to signal the required periodic technical inspection of gas buses. We see that the double difference in particle size is decisive for bus mileage. Assuming that buses in Vilnius are operated in a hilly area, when bus loads change significantly, it is necessary to take this account when assessing their particulate emissions under real road conditions. They can grow significantly and have a direct impact on the health of the urban population.

Based on these research results, three distinct groups of buses can be identified: A, C, and E; B and F; and D. These groups differ in mileage and concentration of the generated particles (Figure 4):



A, C and E buses B and F buses D bus

Figure 4. Atskirų autobusu grupių koreliacinė priklausomybė nuo dalelių koncentracijos ir autobusų kilometražo

According to the correlation, it is observed that the greater the dispersion of the particle concentration results, the weaker the correlation. This tendency is clearly observed in FIG. 4. The mileage of bus D is the highest of all the buses studied, so the highest scattering of the particle concentration results was obtained, and at the same time the weakest correlation. The opposite trend is observed in the scattering of the results of bus groups A, C and E, where the highest correlation was observed.

4. Conclussions

Concentration studies of particles generated by gas buses have shown that:

1. The concentration limits of the particles were sufficiently low and ranged from 400 to 1250 parts. / cm^3, excluding bus D ratings, was 400-600 parts. / cm^3, which is twice less than the results of bus D.
2. The high mileage of a bus increases the dispersion of particle concentration results and at the same time signals the need to diagnose such a bus in order to avoid imminent failure.

The proposed method makes it possible to identify the technical condition of buses depending on the amount of particles generated. The application of this method can be used not only within one company, but also in other companies engaged in passenger transport. It is observed that the lower amount of particles generated by gas buses allows to ensure the concept of a green city, which has a corresponding impact on the health and well-being of the urban population.

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