Int. J. of Thermal & Environmental Engineering
Volume 3, No. 2 (2011) 109-112

Mass and Number Concentration and Size Distribution of Particles Emitted from Diesel Engine

Elzbieta Jankowska

Central Institute for Labour Protection – National Research Institute, Warsaw, Poland, 00-701

Abstract

This paper presents results of research of mass and number concentrations and size distribution particles emitted as Diesel exhaust fumes (DEF). The parameters of fine particles were determined with the gravimetric method (with PCIS samplers and microbalance METTLER TOLEDO type UMX2) and optical methods (DUST-TRAK, P-TRAK, GRIMM, SMPS). Researchers were carried out during the simulation of three 4-hours periods possible exposure of workers to DEF in a garage with switch-on and switch-off Diesel engine located in different positions. Investigations were also done in atmospheric air close to garage before and after measurements performed in the garage.

Keywords: *Diesel exhaust, concentration, ultrafine particles, size distribution*

1. Introduction

Diesel exhaust fumes (DEF) are a complex mixture of particulate and gas phase pollutants. The highly respirable particles consist mainly of a carbonaceous core and adsorbed organic compounds. The most important adsorbed organics are *n*-alkanes and polycyclic aromatic hydrocarbons (PAHs). Much attention has been focused on particulate phase components of diesel fumes due to possible acute and chronic respiratory effects. The IARC has classified Diesel exhaust fumes as probably carcinogenic to humans - class 2A [1-7].

2. Content

In this paper are presented results of measurements of parameters of fine particles emitted from the Diesel engine during simulation of possible exposure of workers to DEF in typical garage. Measurements were done with gravimetric and optical methods.

2.2. Methods

Researches were conducted in the garage used for storage and for repairing cars. Dimensions of garage were following: length of 5,6 m, width of 5 m and height of 3,8 m. DEF was generated with Diesel engine, shown on Fig. 1 (engine was purchased during realization of project PBZ-MEiN-3/2/2006). The Diesel engine was from a car Skoda of Fabia TDI – year 2007. An engine works with Common Rail system.

Investigations were carried out during the simulation of three 4-hours periods of possible exposure of workers in the garage with switch-on and switch-off Diesel engine positioned in one of three location different in each 4-hours period. Sampling points were located about 2,3 m from the source of DEF (location 1) about 3,8 m (location 2) and about 3,3 m (location 3) - Fig. 2. Sampling points and source of DEF were positioned on the height about 1 m from the garage floor.

Measurements of parameters of particles were done with:

- gravimetric method:
  - particles were sampled using Sioutas Cascade Impactor (PCIS) samplers with SKC Leland Legacy Pump operated at 9 l/min; filters for sampling particles were weighted with microbalance METTLER TOLEDO type UMX2,
- optical methods:
  - Aerosol Monitor DUST-TRAK model 8520 (TSI) – mass concentration of particles in the 0,1-10 µm range,
  - Ultrafine Particle Counter P-TRAK model 8525 (TSI) – number concentration of particles in the 0,02-1 µm range,
  - Aerosol Spectrometer and Dust Monitor model 1.108 (GRIMM) number concentration of particles from the ranges: 0,4-0,5 µm, 0,5-1 µm, 1-3 µm and 3-10 µm,
  - Scaning Mobility Particle Sizer SMPS (CPC 3022A and long DMA, TSI) – size distribution of particles in the 15-102 nm range.

* Corresponding author. Tel.: +48226233267
Fax: +48226233693; E-mail: eljan@ciop.pl

DOI: 10.5383/ijtee.03.02.008

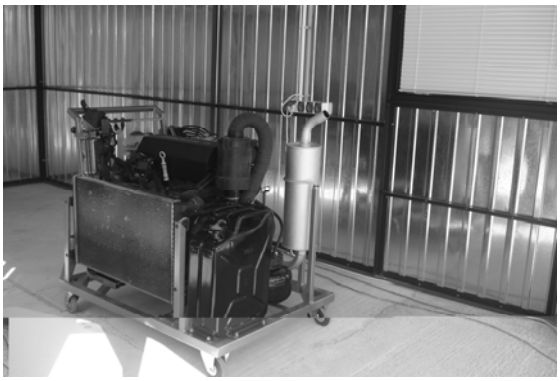

Fig. 1. Diesel engine for generation of DEF in garage

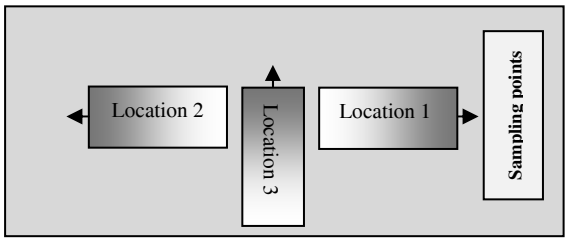

Fig. 2. Location of source of DEF during investigations

Investigations were stated with measurements of parameters of particles suspended in the atmospheric air, close to the garage, using equipment based on optical methods. Before Diesel engine switched on, background level in the garage was determined also with optical methods.

During each 4-hours period of investigation Diesel engine was switched-on four times for 30 min (together 2 hours). Windows and doors in the garage were closed - atmospheric air could get in to the garage only through lacks. The door was open only for few seconds for switched-on or switch-off Diesel engine. Measurements of particles parameters were performed both with optical and gravimetric methods. In each 4-hours period 6 samples of DEF particles with PCIS were taken. Between measurements done during three 4-hous periods the door of garage was open two times for 30 min.

2.2. Results

2.2.1. Mass concentrations of DEF particles - gravimetric method

Samples of particles with a diameter of 0,25 μm or less (fraction $PM_{0,25}$), 0,5 μm or less ($PM_{0,5}$), 1 μm or less (PM_1), 2,5 μm or less ($PM_{2,5}$) and 10 μm or less (PM_{10}) were taken with PCIS samplers (Fig. 3). Mass concentrations determined with gravimetric method are presented in Table 1. Information about part of mass of $PM_{0,25}$, $PM_{0,5}$, PM_1 and $PM_{2,5}$ in fraction PM_{10} (%) are shown in Table 2.

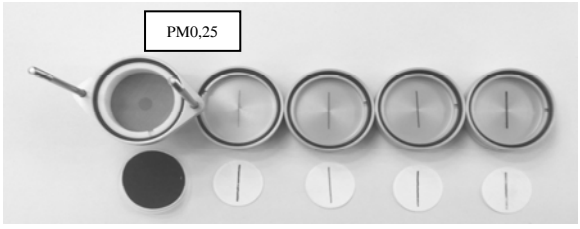

Fig. 3. Example of samples taken with PCIS

Table 1. Mass concentration of fraction $PM_{0,25}$, $PM_{0,5}$, PM_1, $PM_{2,5}$ and PM_{10} in sampling points when Diesel engine was positioned in different locations

Fraction	Mass concentrations (mg/m^3) of fractions $PM_{0,25}$, $PM_{0,5}$, PM_1, $PM_{2,5}$ and PM_{10} in sampling points (6 samples) when Diesel engine was located, in		
	Location 1	Location 2	Location 3
$PM_{0,25}$	1,0250 – 2,2725	1,0643 – 1,4508	1,4064 – 1,8120
$PM_{0,5}$	1,0714 – 2,3046	1,1356 – 1,4812	1,4289 – 1,8329
PM_1	1,1075 – 2,3390	1,1437 – 1,5051	1,4457 – 1,8521
$PM_{2,5}$	1,1337 – 2,3589	1,1557 – 1,5248	1,4646 – 1.8819
PM_{10}	1,1873 – 2,4438	1,2117 – 1,6073	1,6553 – 2,0466

Table 2. Parts of mass of fraction $PM_{0,25}$, $PM_{0,5}$, PM_1, $PM_{2,5}$ in PM_{10} (%)

Fraction	Parts of mass of fractions $PM_{0,25}$, $PM_{0,5}$, PM_1, $PM_{2,5}$ in PM_{10} (%) in sampling points (6 samples) when Diesel engine was located, in		
	Location 1	Location 2	Location 3
$PM_{0,25}$	86 – 94	88– 94	85 – 92
$PM_{0,5}$	90 – 95	89 – 94	86 – 93
PM_1	93 – 96	90 – 94	87 – 94
$PM_{2,5}$	95 – 97	92 – 95	88 – 95

2.2.2. Mass and number concentration and size distribution of DEF particles - optical methods

Results of researches of parameters of ultrafine particles emitted as DEF, measured with optical methods, are presented on:

- Fig. 4 - mass concentration of DEF particles from the range of 0,1-10 μm (DUST-TRAK results),
- Fig. 5 - number concentration of DEF particles from the range 0,02-1 μm (P-TRAK results),
- Fig. 6 - number concentration of DEF particles from the ranges of: 0,4-0,5 μm, 0,5-1 μm, 1-3 μm and 3-10 μm (GRIMM results),
- Fig. 7 - size distribution of ultrafine particles from the range 15-102 nm (SMPS results).

On Figs 4 to 6 are shown results of measurements done for all three 4-hours periods investigations for illustration changes in concentration depended on the location of source of DEF particles. On Fig. 7, as example, are presented results of measurement of size distribution of ultrafine particles for first 4-hours period measurements only. The aim of presentation of the data by this way was showing changes in size distribution of ultrafine particles in different measurements situations. Particles size distribution of ultrafine particles (from the range 15-102 nm) are respectively illustrated on:

- Fig 7a):
  - in atmospheric air close to garage before measurements done during first 4-hours period,
  - as background in the garage,
  - after first 4-hours period - 30 min after open the door of garage,
- Fig 7b):
  - 30 min after Diesel engine was switch-on four times (1,2,3,4) in first 4-hours period of measurements,
- Fig 7c):
  - 30 min after Diesel engine was switch-off three times (1,2,3) and 15 min after switch-off fourth time (4) in first 4-hours period of measurements.

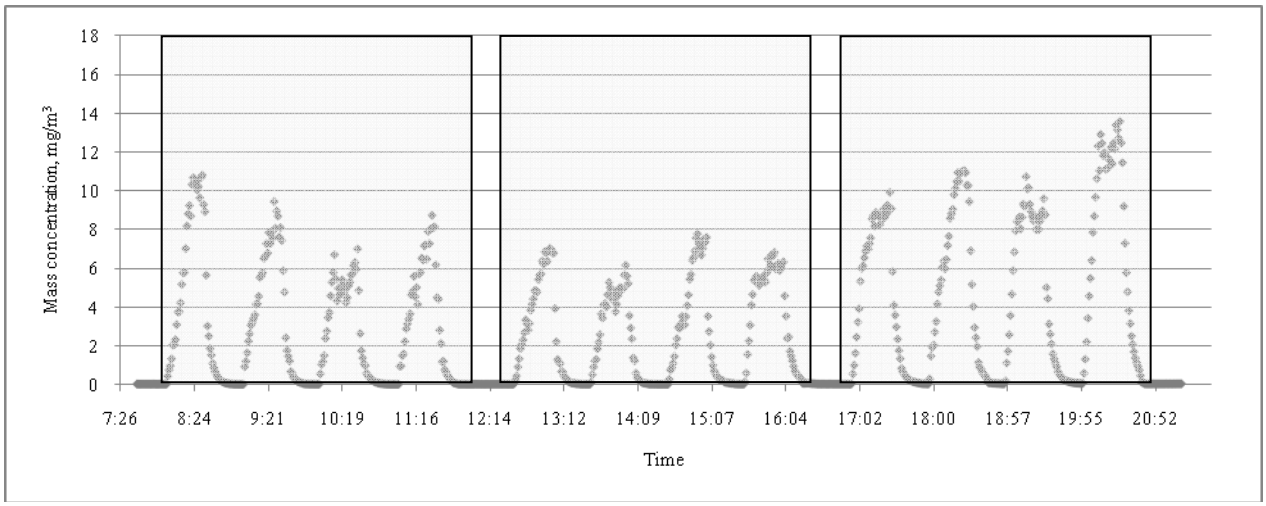

Fig. 4. Mass concentration of DEF particles from the range of 0,1-10 µm (DUST-TRAK results) - grey boxes are showing three 4-hours measuring periods

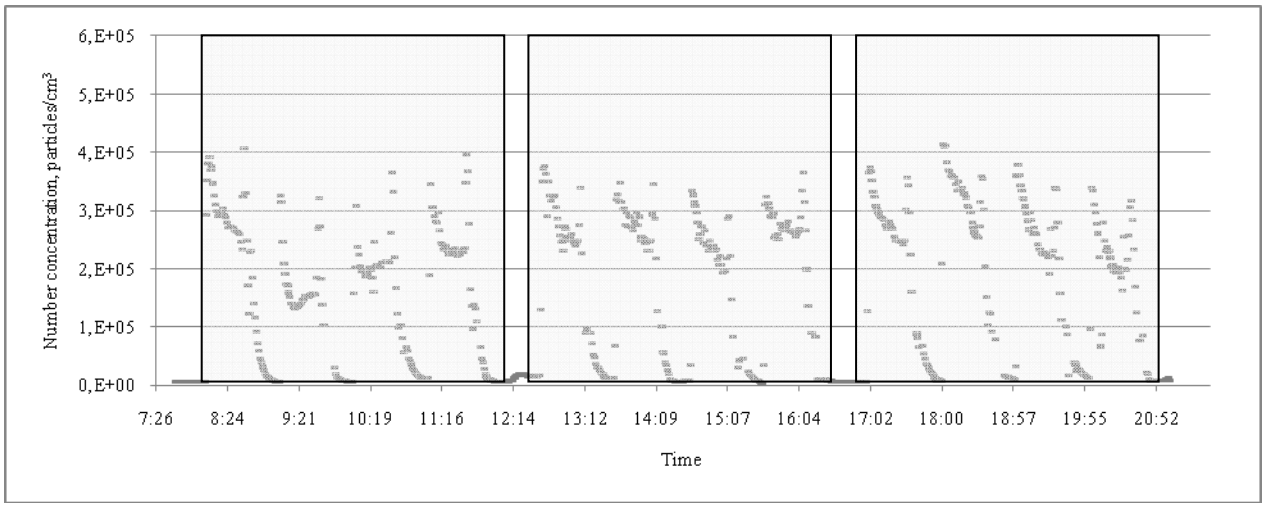

Fig. 5. Number concentration of DEF particles from the range of 0,02-1 µm (P-TRAK results) - grey boxes are showing three 4-hours measuring periods

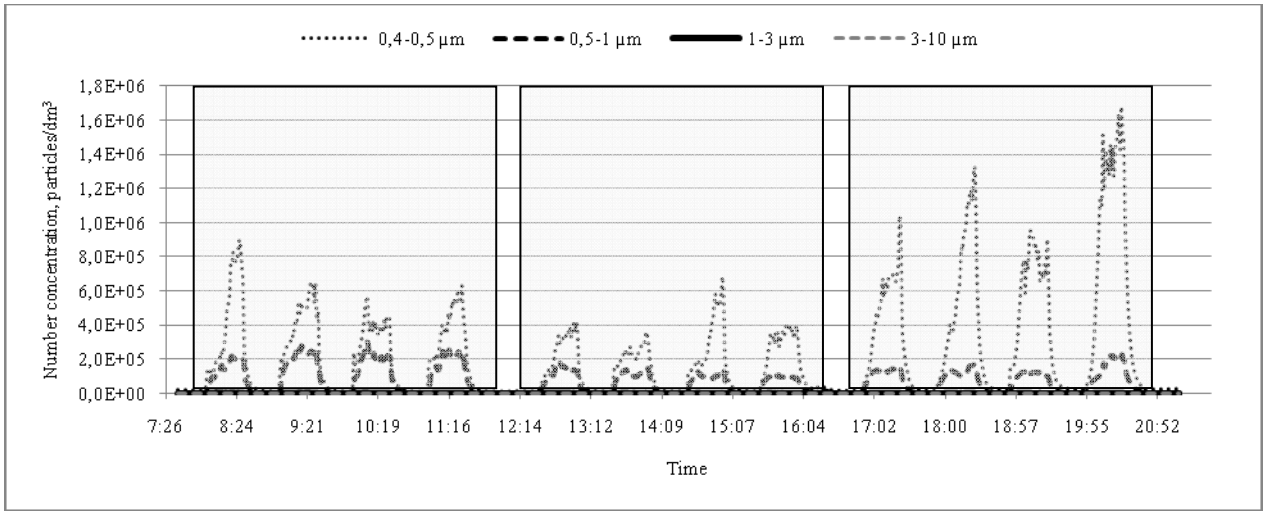

Fig. 6. Number concentration of DEF particles from the ranges of: 0,4-0,5 µm, 0,5-1 µm, 1-3 µm and 3-10 µm (GRIMM results) - grey boxes are showing three 4-hours measuring periods

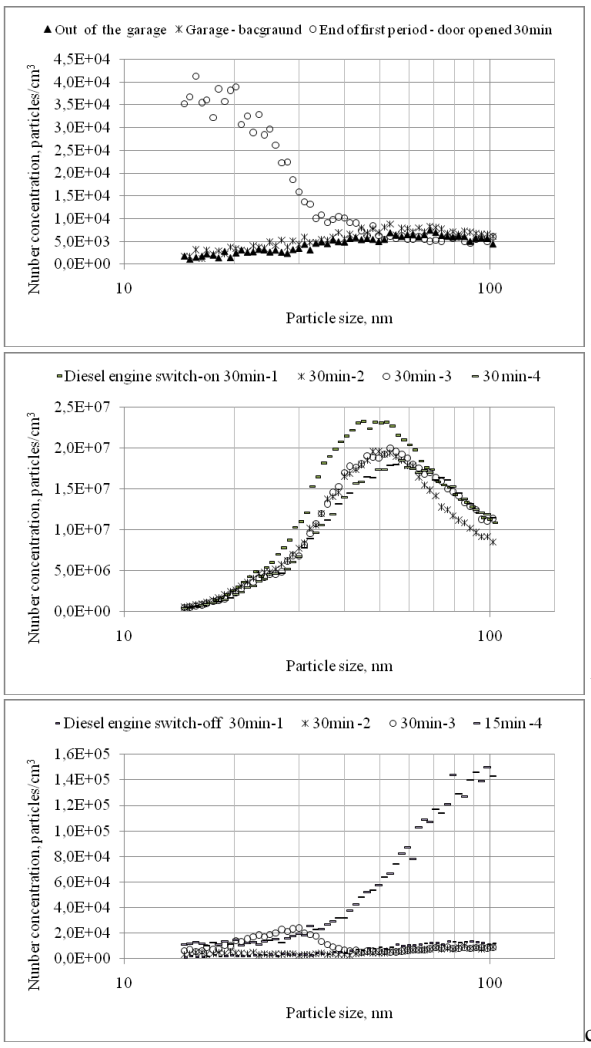

Fig. 7. Size distribution of ultrafine particles from the range 15-102 nm (SMPS results):

a) before measurements done during first 4-hours period (in atmospheric air close to garage and background in the garage) and after first measurement period (30 min after open the door of garage),

b) 30 min after Diesel engine was switch-on four times (1,2,3,4) in first 4-hours period of measurements,

c) 30 min after Diesel engine was switch-off three times (1,2,3) and 15 min after switch-off fourth time (4) in first 4-hours period of measurements.

3. Conclusion

As results from Table 1 it is not possible to asses influence of location of source of DEF on concentration of fraction $PM_{0,25}$, $PM_{0,5}$, PM_1, $PM_{2,5}$ and PM_{10} in taken samples. Generally, mass concentrations fraction in all locations - as results received for 18 samples - are included in the ranges: 1,03–2,3 mg/m^3 ($PM_{0,25}$), 1,07–2,31 mg/m^3 ($PM_{0,5}$) 1,11–2,34 mg/m^3(PM_1) 1,13–2,36 mg/m^3 ($PM_{2,5}$) and 1,19–2,44 mg/m^3 (PM_{10}). Taken samples contained mostly fraction $PM_{0,25}$ (Table 2). Parts of mass in PM_{10} fraction was following: 85–95% $PM_{0,25}$, 86–95% $PM_{0,5}$, 87–96% PM_1 and 88–97% $PM_{2,5}$.

DUST-TRAK results shown (Fig. 4) that during the time when Diesel engine was switch-on mass concentration increased significantly up to about 11 mg/m^3 in first period of measurements, up to about 10 mg/m^3 in second period and up to about 14 mg/m^3 in third period. Results from Fig. 4 shown that concentrations during engine switch-on were the highest in location 3 in the measurements done in the end of the day.

There is not visible differences between results for three 4-hours period measurements obtained with P-TRAK. In all scenarios number concentration increased very rapidly after switching-on Diesel engine, up to about 4e^{+05}particles/cm^3.

Similar tendency like for DUST-TRAK results were observed for measurements done with GRIMM (Fig. 6) – the highest number concentrations were also observed in location 3. Data obtained for particles from the ranges: 0,4-0,5 µm, 0,5-1 µm, 1-3 µm and 3-10 µm confirmed that DEF contains mostly fine particles. Amounts of particles from the ranges: 1-3 µm and 3-10 µm are proportionally smaller.

Size distribution of ultrafine particles (SMPS, Fig. 7) obtained for atmospheric air and for the background in the garage were similar (Fig. 7a). But after first 4-hours period measurements - 30 min after open the door of the garage - big amount of small particles with diameter less than 20 nm were observed. After 30 min, when Diesel engine was switch-on, size distributions in four times (1,2,3,4 - Fig. 7b) had similar values and shapes. After 30 min, when Diesel engine was switch-off, in three times (1,2,3 – Fig. 7c) values and shapes of size distributions were similar, excluded time (3), but 15 min after switch-off fourth time (4) proportionally big amount of particles from the range 40-100 nm were presented in the air of garage.

Acknowledgments

This study was prepared on the basis of the results of research project 2.R.03 carried out within the scope of the National Programme "Improvement of Occupational Safety and Working Conditions" supported by the Polish Ministry of Science. Main co-ordinator CIOP-PIB.

References

[1] Health Assessment Document for Diesel Engine Exhaust. EPA/600/8-90/57F, 2002.

[2] Laden F., Hart J. E., Eschenroeder A., Smith T. J., Garshick E. Historical estimation of diesel exhaust exposure in a cohort study of U.S. railroad workers and lung cancer. Cancer Causes Control. 2006, 17:911–919, doi:10.1007/s10552-006-0027-5

[3] Desantes J.M., Margot X., Gil A., Fuentes E. Computational study on the deposition of ultrafine particles from Diesel exhaust aerosol. Journal of Aerosol Science, 2006, 37, 1750–1769. doi:10.1016/j.jaerosci.2006.07.002

[4] Brich M. E., Cary R.A. Elemental Carbon-Based Method for Monitoring Occupational Exposure to Particulate Diesel Exhaust. Aerosol Science and Technology.1996, 25, 221-241. doi:10.1080/02786829608965393

[5] Diesel and gasoline engine exhausts and some nitroarenes. IARC monographs on the evaluation of carcinogenic risks to humans.46, 41-185, Lyon1989.

[6] Jankowska E., Pośniak M., Walicka E. Makhniashvili I. Size distribution, concentration and chemical components of fine particles of Diesel exhaust fumes. Proceedings of the 3rd International Symposium on Nanotechnology, Occupational and Environmental Health, Taiwan, 2007.

[7] Burtscher H. Physical characterization of particulate emissions from diesel engines: a review. Journal of Aerosol Science 2005; 36, 896–932. doi:10.1016/j.jaerosci.2004.12.001