



Emissions from a diesel generator

Report no. 218911



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1. Description of assignment

Clayton Power appointed Danish Technological Institute to perform indicative measurements for determining the level of pollution a person is exposed to when a diesel or a petrol generator is in operation nearby. These generators are used on construction sites to operate power tools, e.g., for welding. Measurements of ultrafine particles and black carbon were performed for each generator at four different locations, where an operator would typically be situated. The measurement duration at each position was 5-10 minutes.

2. Conclusion

The table below shows the average pollution levels for a 20-kW diesel generator located on a trailer and a petrol generator located in the load space of a van, measured in the positions where these levels were, respectively, highest and lowest. The table shows black carbon measured with MA200 and ultrafine particles measured with NanoScan instruments (see also Table 1 on page 7 for the complete measurement results).

	Black carbon [$\mu\text{g}/\text{m}^3$]	Ultrafine particles [particles/cm^3]
Diesel generator		
Next to generator	1.04	24,400
7-8 m from generator	1.28	8,700
Petrol generator		
Behind rear door of van	980	5,170,000
3,8 m from generator	42.3	146,000

The occupational exposure limit (for Denmark) to diesel particles is $10 \mu\text{g}/\text{m}^3$ over one working day (8-hour average) and $20 \mu\text{g}/\text{m}^3$ for short-term exposure (15-minute average). There exist no limits for black carbon or ultrafine particles. According to the World Health Organization (WHO), particle concentrations of ultrafine particles should be considered *high* if the hourly average exceeds 20,000 particles/ cm^3 .

For sake of comparison, on H. C. Andersens Boulevard (a trafficked street in the center of Copenhagen, where a national air quality monitoring station is located), the annual average of black carbon and ultrafine particles was $1.0 \mu\text{g}/\text{m}^3$ and 10,000 particles/ cm^3 , respectively.



3. Procedure

3.1. Measurement location

On Friday, December 1st 2023, Clayton Power brought a van with a petrol generator in the load area and a trailer with a diesel generator on it to the Danish Technological Institute (Kongsvang Allé 31, Aarhus C). The measurements were performed between 9 and 11 am, when the average wind speed was low (2.3 m/s from a northerly direction).¹ The generators were placed in a car parking, behind a building blocking the southward wind (see Figure 1 on page 5), in order to obtain worst-case scenario measurements of the emissions from the generators. The wind was anyway generally calm except for a few strong gusts.

3.2. Measurement of ultrafine particles and black carbon

Measurements of particle pollution were performed with three instruments: TSI NanoScan SMPS 3910 (abbr.: NanoScan), TSI Condensation Particle Counter 3007 (abbr.: CPC) and AethLabs MA200 (abbr.: MA200). Due to mild snow precipitation on the day, the measuring instruments were packed in a transparent box (Figure 2, page 6) with hoses attached to the instruments' inlets inserted. Due to the very small size of the particles under investigation, it is assumed that the sampling through hoses didn't perturb the determination.

Ultrafine particles

Ultrafine particles, *i.e.*, particles with a diameter of 10-100 nm, were measured with the NanoScan and CPC. The measuring principle is similar for both instruments: the airborne ultrafine particles are drawn into a chamber saturated with isopropyl alcohol vapor, which condenses on the ultrafine particles. This causes the particles to grow in size, making possible to optically detect them based on the scattering of a laser beam.

The CPC measures the particle number concentration (number of particles per cubic centimeter, particles/cm³) of ultrafine and fine (10-1000 nm in diameter) particles, with a time resolution of 1 second. The NanoScan provides the size distribution of particles with diameter of 10-400 nm, with a time resolution of 60 seconds. In this report, only the concentration of ultrafine particles (10-100 nm) is given for the NanoScan.

The CPC and NanoScan can reliably measure particle number concentrations up to 10⁵ particles/cm³ and 10⁶ particles/cm³ respectively; particle concentrations above these limits are underestimated.

¹ DMI's weather archive, Aarhus.



Black carbon

Black carbon consists mainly of carbon atoms that clump together into ultrafine particles, typically around 100 nm in size, and is formed during combustion processes. Black carbon was measured with a MA200, which is an *aethalometer* that measures the particles' light absorption at 5 different wavelengths and identifies black carbon based on its unique light absorption properties.

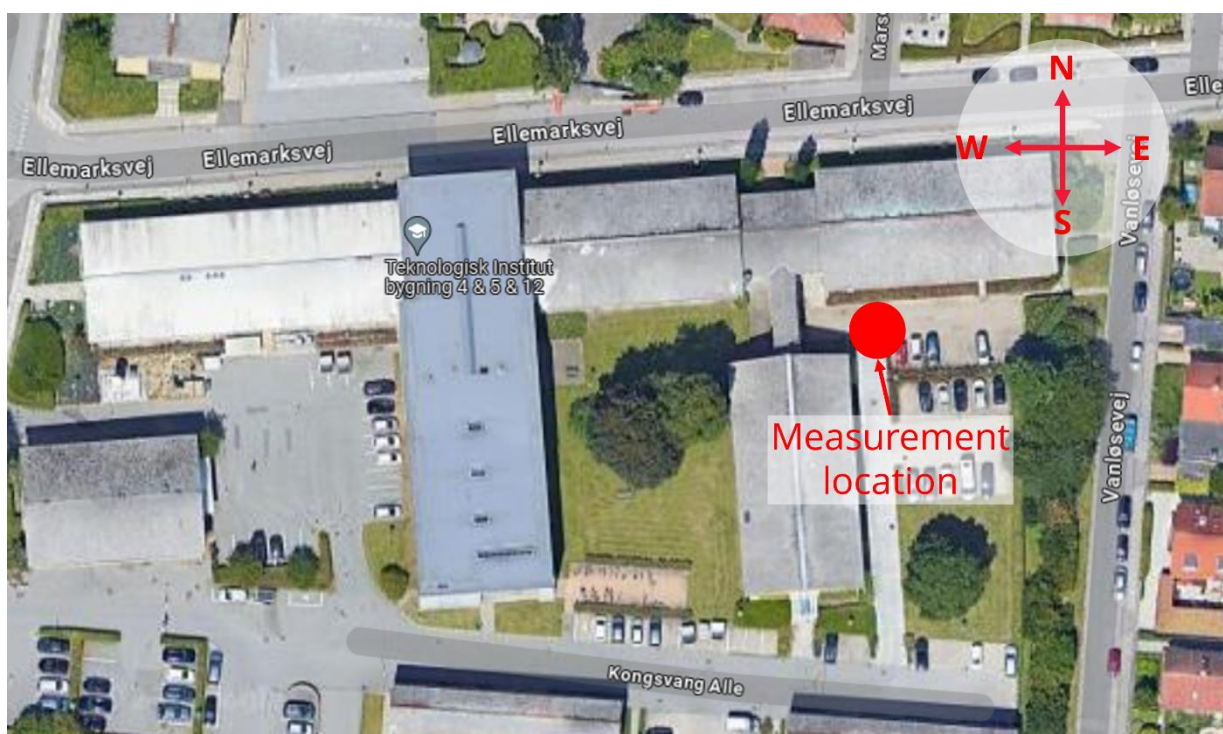


Figure 1. Location of the diesel and petrol generators (red dot) on the map.

Measurements next to the diesel generator

Measurements lasting 10 minutes each were taken next to the diesel generator with the measuring equipment placed in four different locations (see Figure 5 to Figure 8 on page 11-14 in the appendix):

1. Immediate vicinity of the diesel generator.
2. 180 cm from the diesel generator.
3. 300 cm from the diesel generator.
4. 700-800 cm from the diesel generator.

Measurements next to the petrol generator

Measurements lasting 5-10 minutes each were taken next to the petrol generator located in the van with the side and rear doors open, with the measuring equipment placed at four different locations (see Figure 9 to Figure 11 on page 15-17 in the appendix):



1. Inside the van next to the petrol generator.
2. At the side door of the van, 270 cm from the petrol generator.
3. Immediately behind the rear door of the van, 130 cm from the petrol generator.
4. 150 cm from the rear door of the van, 380 cm from the petrol generator.

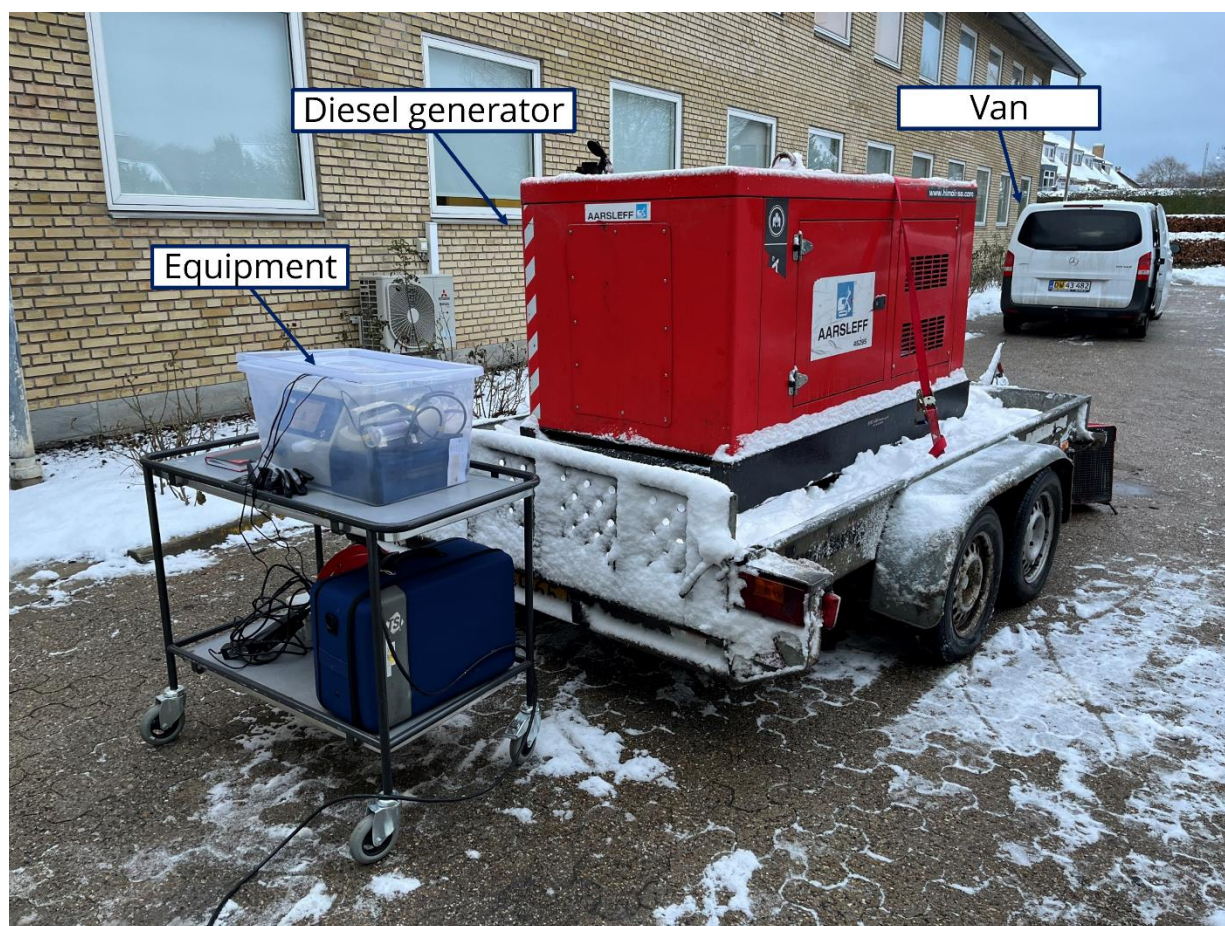


Figure 2. Position of the measuring equipment (NanoScan, CPC and AE200 in the transparent plastic box) in front of the diesel generator.



4. Results

The measured time series of the concentration of black carbon and ultrafine particles produced by the diesel and the petrol generators are shown in Figure 3 and Figure 4 on page 9 and 10. Four intervals are highlighted in the graphs, corresponding to the measurements at the previously defined positions 1 (orange), 2 (light blue), 3 (green) and 4 (yellow). The average values of the measured concentrations are shown in Table 1.

Table 1. Average values of concentration of black carbon and ultrafine particles produced by the diesel and the petrol generator at positions 1, 2, 3 and 4.

	Black carbon [ug/cm³]	Ultrafine parti- cles (CPC) [particles/cm³]	Ultrafine parti- cles (NanoScan) [/cm³]
Diesel generator			
Position 1	1.04	30,700	24.400
Position 2	1.26	28,600	20.800
Position 3	1.84	26,500	20.800
Position 4	1.28	17,000	8.700
Petrol generator			
Position 1	0.52	263,000	3,450,000
Position 2	23.8	73,700	135,000
Position 3	980	473,000	5,170,000
Position 4	42.3	91,400	146,000

The emissions of black carbon and ultrafine particles from the petrol generator are significantly higher than from the diesel generator. Here, the discrepancy in the measurements of ultrafine particles between the CPC and NanoScan is due to the CPC's underestimation of particle concentrations exceeding 10^5 particles/cm³, while the NanoScan underestimates particle concentrations above 10^6 particles/cm³.



The occupational exposure limit (for Denmark) to diesel particulates is 10 $\mu\text{g}/\text{m}^3$ over one working day (8-hour average) and 20 $\mu\text{g}/\text{m}^3$ for short-term exposure (15-minute average).²

As for today, there exist no limits or guidelines for exposure to black carbon and ultrafine particles. According to WHO, the concentration of ultrafine particles should be considered high if the hourly average exceeds 20,000 particles/ cm^3 .³

The current concentration values are compared here with the particle pollution present on H.C. Andersen Boulevard in Copenhagen, shown in Table 2. The values are average values over the year 2019. Note that the pollution levels can be significantly higher than the annual averages during peak traffic hours; according to measurements from 2022, the maximum hourly average on H. C. Andersen Boulevard was 85,000 particles/ cm^3 .⁴

Table 2. Annual averages from 2019 of the concentration of ultrafine particles and black carbon measured on H. C. Andersen Boulevard in Copenhagen. The table has been reproduced from DCE's report on air pollution in Copenhagen.⁵

	Ultrafine particles [particles/cm^3]	Black carbon [$\mu\text{g}/\text{m}^3$]
Annual average value 2019, H. C. Andersen Boulevard	10,000	1.0

² Bekendtgørelse om grænseværdier for stoffer og materialer (kemiske agenser) i arbejdsmiljøet [Executive Order on limit values for substances and materials (chemical agents) in the working environment]. <https://www.retsinformation.dk/eli/ta/2023/2023-01-11/1>

³ WHO global air quality guidelines (2021), p. 150. <https://iris.who.int/bitstream/handle/10665/345329/9789240034228-eng.pdf>

⁴ Thomas Ellermann. 2023. Måling af partikler omkring Københavns Lufthavn i Kastrup – status september 2023 [Measurement of particles around Copenhagen Airport in Kastrup - status September 2023]. Aarhus University, DCE - Danish Centre for Environment and Energy, 26 p. - Scientific note no. 2023 | 45. https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2023/N2023_45.pdf

⁵ Ellermann, T., Khan, J., Ketzel, M., Jensen, S.S. & Hertel, O. 2021. Air View Data on the spatial distribution of air pollution in Copenhagen. Aarhus University, DCE - Danish Centre for Environment and Energy, 27s. - Scientific note no. 2021 | 40. https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2021/N2021_40.pdf

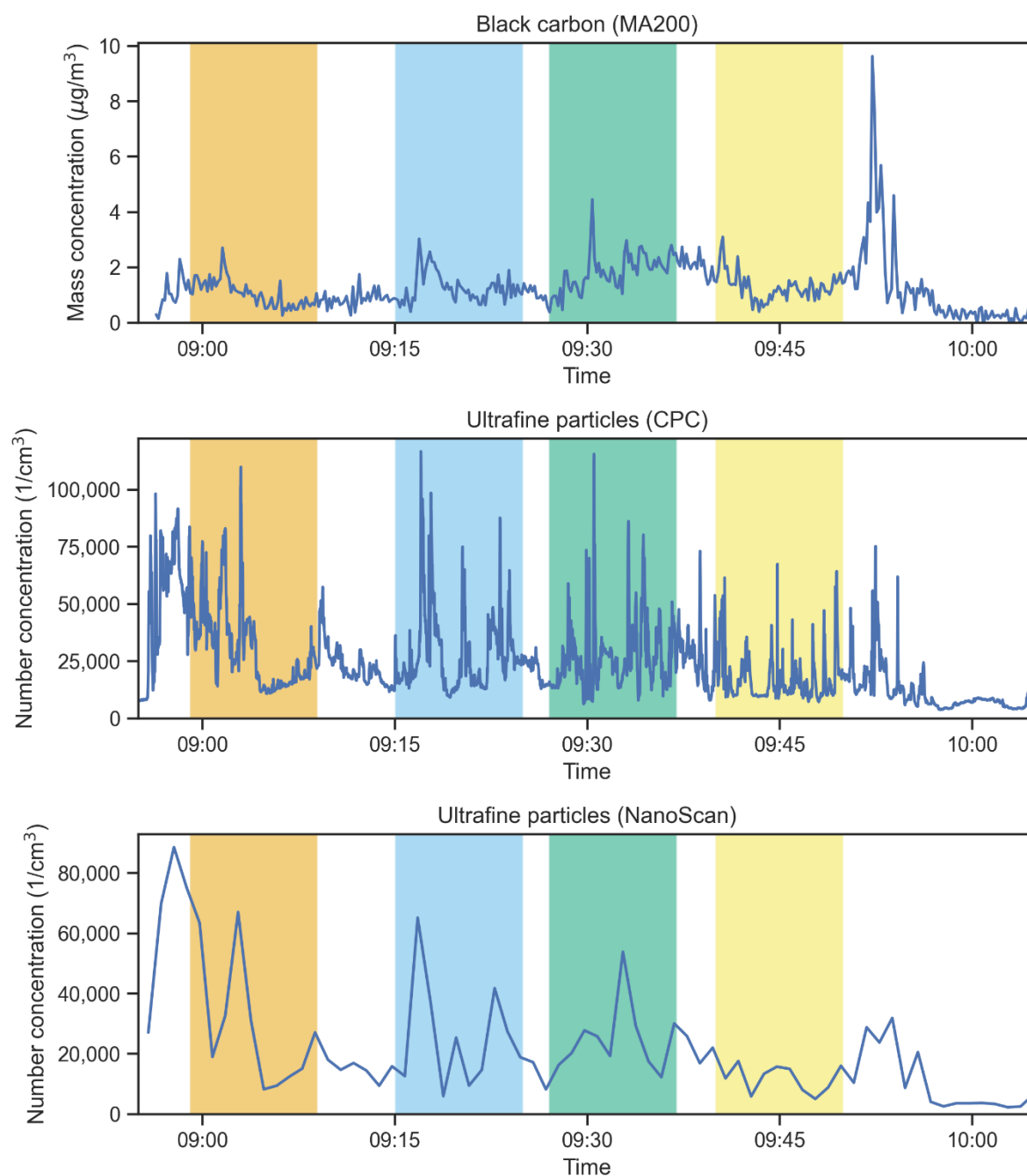


Figure 3. Concentration measurements of black carbon (top) and ultrafine particles (middle and bottom with CPC and NanoScan, respectively) from the diesel generator. The colored areas indicate, in order, the time interval of the measurements at positions 1, 2, 3 and 4.

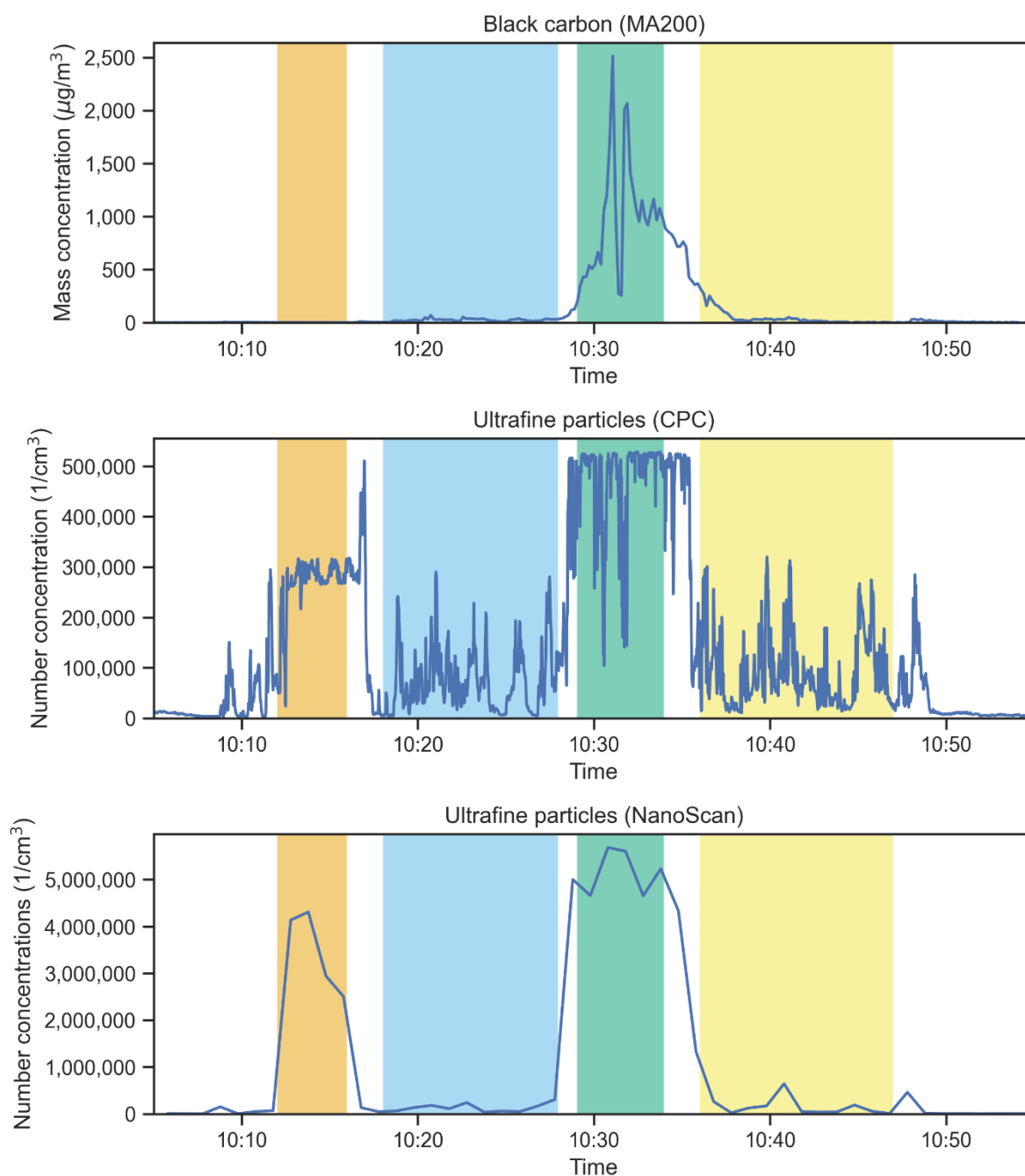


Figure 4. Concentration measurements of black carbon (top) and ultrafine particles (middle and bottom with CPC and NanoScan, respectively) from the petrol generator. The colored areas indicate, in order, the time interval of the measurements at positions 1, 2, 3 and 4.



5. Appendix

5.1. Measurement locations for the diesel generator



Figure 5. Measurement position 1, near the diesel generator.



Figure 6. Measurement position 2, 190 cm from the diesel generator.



Figure 7. Measurement position 3, 300 cm from the diesel generator.



Figure 8. Measurement position 4, 700-800 cm from the diesel generator.



5.2. Measurement locations for the petrol generator



Figure 9. Measurement position 1, inside the van next to the petrol generator.



Figure 10. Measurement position 2, next to the side door of the van, 270 cm from the petrol generator.



Figure 11. Measurement positions 3 and 4, behind the rear door of the van, respectively 130 and 380 cm from the petrol generator.



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