Determinants of particulate pollution within the Lille subway trains

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ABSTRACT
PM concentrations within the subway trains in Lille conurbation (northern France) have been measured since May 2017, using the small, mobile, autonomous systems we are developing. Elevated levels of PM_1, $PM_{2.5}$ and PM_{10} are consistently observed, with concentrations over the guidelines enforced for outdoor air. The dynamics and levels of the PM concentrations within the trains are influenced by the concentration outdoors and within the train stations, by the affluence within the trains, by the speed of the trains, but mostly by the pollution levels within the subway tunnels.

1. INTRODUCTION

In many cities, the local authorities are promoting the use of public transportation systems instead of individual motor vehicles, to reduce the road traffic and the associated pollutant emissions. This has prompted in the last decade much research on the air quality within the subway stations, and to a lower extent inside the subway trains, and on the exposure of commuters, with several hundreds of published studies on the subject [1], including the impacts on health and the exposure of subway workers. These studies have shown that in many cases the pollution levels within the subway systems can be quite elevated, because of the accumulation of particles and gaseous pollutants in the tunnels, despite ventilation systems. The limited dispersion of pollutants in the tunnels can possibly be aggravated when the tunnels are isolated from the stations by platforms screen doors, such as were installed since the conception of the Lille subway system in 1983. In the present study, we present preliminary findings on the exposure of commuters on one the lines of the Lille subway, and on the determinants of particulate pollution, using portable real-time particle sensors developed in the lab.

2. METHODOLOGY

2.1 PMsensors

The portable devices used in this study were assembled in the laboratory. They are built around a commercial HK-A5 laser $PM_{2.5}/PM_{10}$ sensor, which counts all the particles with an optical diameter between 0.3 and 10 µm, with a response time better than 10 s. The devices communicate to a cell phone via Bluetooth protocol thanks to an API developed in the lab. The cell phone provides the geopositioning (when GPS signal available), stores the results for further analysis, and allows real time visualization of the PM concentrations. A complete (T, RH, P, particle composition…) metrological study of the sensors is underway, and is not presented here. Still, the accuracy of the results from the handheld devices has been checked since early 2017 against laboratory instruments and against the data from the closest pollution monitoring station from the French regulatory organization ATMO, with a correlation coefficient close to 1. For this preliminary work, we only use the particle mass concentration provided by the sensors, and not the particle number densities which are the primary parameters measured by the device.

2.2 Sampling methodology

Measurements were taken between May and December 2017, on the subway line connecting Lille center city and the university campus. No particular strategy was adopted for the selection of the trips, and most of these were carried out during the morning and evening peak hours. During these trips, the PM sensor was directly carried by the bearer, or attached to his/her bag, so the position of the sensor within the train, its height, and the immediate surroundings, differ from on measurement to the other. In that respect, we do not aim to a highly metrological study, which would have required a fixed position, but on the contrary we explore reasonably well the exposure of people within the train whatever their position, sitting or standing, close to the doors or in the middle of the train…

3. RESULTS AND DISCUSSION

A typical example of data acquired during one of the trips is presented on Figure 1. Indoor concentrations (before 11:40) are lower than outdoor concentration (11:40-11:45), with a maximum of PM_{10} around 10 µg.m^{-3}. Concentrations much higher are observed during the rides in the subway train, in particular in the underground part of the line, with concentrations of PM_{10} reaching the 80 µg.m^{-3} threshold used for outdoor air, with $PM_{2.5}$ in excess of 60 µg.m^{-3}, and PM_1 of almost 50 µg.m^{-3}. Similar concentration profiles were obtained for each ride, mainly differing by the maximal concentration reached, ranging for PM_{10} from about 20 to over 100 µg.m^{-3}. In between stations, the concentrations rise slowly as the train gains speed, and usually drop sharply, but not much, when the doors open at the next station. Only in a few cases did we observe an increase of the concentrations when the doors open. This indicates that the air in the station is usually less polluted than the air in the trains. At the same time, this also indicates than the air inside the tunnels is highly polluted, and that the filtration system of the trains is not adequate or sufficient to provide acceptable levels of particles for the commuters. This is also substantiated by the observation of transient concentration peaks when the train is at a station, and another train is coming to a halt into the station, leading to a high production of additional particles from the frictional wear of brake pads, wheels and rails [2]. In that respect, the presence of platforms screen doors, while helping reduce the concentration of particles in the stations [3], is not efficient to reduce the pollution levels within the trains. In addition, a rough correlation was observed with the occupancy of the trains, hinting that a part of the particles are resuspended by the commuters.

4. CONCLUSIONS

This preliminary study showed that the particle pollution levels inside the trains of the Lille subway systems are far from satisfactory, and could possibly induce negative effects on the health of the commuters. These results shed some light on the parameters influencing the particle mass concentration levels. No data could be obtained so far from the public transportation company on the occupancy of the trains, on their speed and position, nor on the ventilation and filtration system, which could help in the interpretation of the measured concentrations, and in the designing of a more efficient ventilation system inside the trains.

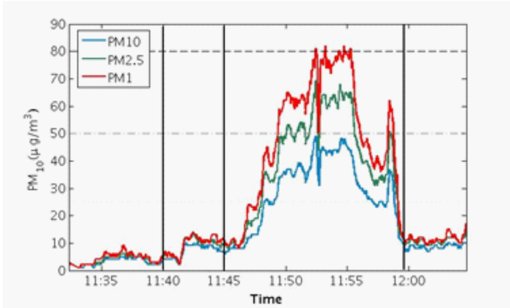

Figure 1 Typical PM profile during a subway ride.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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