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Impact of train braking systems on particle levels in the Paris subway

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Abstract

Several factors can explain the high levels of particle concentrations in underground transportation systems. One of the main particle sources is train's mechanical braking system. The mechanical braking is decreasing with the renewal of rolling stock, new trains have other brake kind: the electrodynamic braking. This technology decreases the mechanical braking use and this one is more and more efficient on new trains.
Two stages have been planned to study the brake technology (with electrodynamic braking //without electrodynamic braking) on particulate air pollution. PM2.5 mass concentration and PM10 mass concentration were simultaneously measured at Colonel Fabien subway platform. The chemical composition of the fine particle fraction (PM2.5) and the coarse fraction (PM10-2.5) is measured using PIXE analysis.
In this campaign, the brake technology has an impact on the air quality. The electrodynamic braking use lowers the PM10 mass concentration by a factor of 4.3. Moreover, the train's mechanical braking system is responsible for a higher iron mass percentage in the coarse particle fraction.

Keywords: subway, air quality, train, indoor

1 Introduction

Paris Public Transport (RATP) services include sixteen subway lines and parts of the Paris regional express railway network. High levels of particle concentrations have been observed by Delaunay et al. (2010) in subway stations. Several particle sources explain these levels in subway systems : wear of rail tracks, wheels and braking pads. The station characteristics (area, volume), the air change rate and train traffic are decisive parameters on particulate matter levels in subway system.

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2 Objectives

In railway environments, one of the main particle sources is train's mechanical braking system. The mechanical braking is decreasing with the renewal of rolling stock, new trains have other brake kind : the electrodynamic braking. This technology decreases the mechanical braking use and this one is more and more efficient on new trains. When the electrodynamic braking is performed, the motors operate as generators and convert the kinetic mechanical energy into electrical energy. This study has been planned to study the brake technology on particulate air pollution (two stages, step I : with electrodynamic braking ; step II : without electrodynamic braking).

Both braking modes were studied on a part of the subway line 2 between October 3 and December 19, 2013 at the Colonel Fabien subway platform. Monitoring of PM10 and PM2.5 were performed using tapered element oscillating microbalance instruments (TEOM). The chemical composition of the fine particle fraction (PM2.5) and the coarse fraction (PM10-2.5) is measured by PIXE analysis (Particle Induced X-ray Emission). Metals analyzed by this method are : Cr, Mn, Fe, Ni, Cu, Zn, As, Sr, Cd, Zr, Mo, Sn, Sb, Ba and Pb.

3 Results

PM10 and PM2.5 mass concentration means during the campaign are summarized in Table 1.

Table 1: PM10 and PM2.5 mass concentration means for each stage.

Stage	PM10 ($\mu g/m^3$)	PM2.5 ($\mu g/m^3$)
I	220	110
II	960	380

PM10 mean concentrations were higher without the electrodynamic braking (II) compared to the stage I by a factor 4.3. PM2.5 mean concentrations were also higher without electrodynamic braking (II) by a factor 3.4. Therefore the electrodynamic braking has a greater impact on the reduction of PM10 mass concentration. The chemical composition of the fine particle fraction (PM2.5) and the coarse fraction (PM10-2.5) for each stage highlights the large presence of iron in the mass percentage. This large presence of iron can be explained by a previous study. According to Fischer (2003), wear of braking pads reveals the preponderant presence of iron (between 50 and 80% of the dust mass). Copper, barium, manganese, silicon, calcium and sulfur are also present in the studied breaking

pads. The mass percentage of iron in each stage is presented in the Table 2.

Table 2: Mass percentage of iron in the coarse fraction and the fine particle fraction

Stage	PM2,5-10 (%)	PM2.5 (%)
I	38	38
II	33	28

4 Conclusion

Without electrodynamic braking, the results reveal a higher iron mass percentage in the coarse particle fraction compared to the fine fraction. Therefore train's mechanical braking system increases iron mass percentage in the coarse particle fraction. Furthermore the brake technology has an impact on the particle levels. In this campaign, electrodynamic braking lowers the PM10 mass concentration by a factor of 4.3. The renewal of rolling stock with an electrodynamic braking optimized on the new trains is carried out on several subway lines.

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