Impact of train braking systems on PM10 mass concentrations in the Paris subway

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Paris Public Transport (RATP) services include sixteen subway lines and parts of the Paris regional express railway network. In subway stations, high levels of particle concentrations have been observed by Delaunay *et al* (2010). These levels can be explained by the particulate sources 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.

In railway environments, the mechanical braking of trains is one of the main particulate sources. This source decreases with the renewal of rolling stock, the new trains have another brake type : the electrodynamic braking. This technology avoids the mechanical braking 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.

Both braking modes were studied on a part of the subway line 2 between October 3 and December 19, 2013 on subway platform at Colonel Fabien station. 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 method (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.

Two stages have been planned to study the brake type impact on particulate air pollution (I : with electrodynamic braking ; II : without electrodynamic braking). 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

The results reveal a mass percentage of iron higher in the coarse fraction compared to the fine fraction in the stage II unlike the stage I. Therefore the mechanical braking of trains is responsible of the iron mass percentage higher in the coarse fraction. Furthermore this particulate source has also a greater impact on the particle levels.
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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