The effect of ventilation protocols on subway air quality

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SUMMARY
There are several factors controlling PM concentrations in underground systems, e.g. type of ventilation, station depth, date of construction and station design, composition of wheels, railtracks and brakes, train speed and frequency, passenger density, and the presence or absence of platform screen doors. The length of the effect of these variables, especially those which can be modified in already-built stations, is important to be known to further produce a strategic plan designed to improve air quality in subway systems worldwide. Regarding air quality at platforms and inside trains, sampling campaigns were scheduled in the framework of the IMPROVE LIFE project aiming to check the impact on passenger’s exposure to air pollutants attributed to modifications on the: 1) air flow direction; 2) air flow intensity; 3) air conditioning inside the trains.

PRACTICAL IMPLICATIONS
The selection of the right ventilation protocol in the subway premises is one of the key factors to achieve better air quality in platforms and inside trains.

KEYWORDS
Subway platform, ventilation, particulate matter, air conditioning, tunnel.

1 INTRODUCTION
Air quality plans incentivise the use of public transport to abate atmospheric emissions from private road vehicles in cities. In this context rail subway systems are especially desirable as they are based on electric trains, are energetically/environmentally efficient, and help relieve surface traffic congestion. However, a number of studies have revealed poor air quality underground, especially concerning levels of Particulate Matter. In this context, the IMPROVE LIFE project has the clearly defined objective of providing local and national transport authorities of European countries with a protocol for recommended measures to enable them to reduce concentrations of particulate matter and improve air quality in the subway environment. Special emphasis has been done to study the effects of different ventilation protocols in the air quality of platforms and inside trains.

2 MATERIALS/METHODS
A series of campaigns were performed at platforms on the Barcelona subway system, with different ventilation protocols being implemented at the stations. Sampling devices were located at the end of the platform corresponding to the train entry point, behind a light fence for safety protection. Air monitoring equipment include: i) a light-scattering laser photometer
(DustTrak 8533, TSI) for PM2.5 mass concentrations; ii) an optical particle sizer (OPS 3330, TSI) to measure number size distributions in the size range 0.3–10μm; iii) a high volume sampler (CAV-A/MSb, MCV) with a PM2.5 head for gravimetric and chemical analysis; and iv) an indoor air quality meter (IAQ-Calc 7545, TSI) for CO, CO2, T and RH values. Continuous measurements (24h/day) with a 5-min time resolution were performed using the OPS, the DustTrak monitor, and the IAQ-Cal. A DustTrak monitor was also installed inside one of the driver’s cabins in a train with the same ventilation system as the rest of the carriage. Measurements started when all air conditioning filters along the train were replaced, and were changed after one, two and three months to evaluate its possible effects on air quality.

3 RESULTS & DISCUSSION
The detailed experiments on platform/tunnel ventilation have yielded the following results:

1. Modifications on the air flow direction. Better PM air quality is achieved by forceful introduction of outdoor air (impulsion) in tunnels rather than by the extraction of indoor air. The outdoor air is just taken from outside without any filtering process. PM2.5 and N0.3-10 mean levels are 18-22% higher when only extraction is operating in the tunnels and platforms (PM2.5: 77 vs 62μg/m3; N0.3-10: 1713 vs 1340#/cm3), while CO2 levels climb 10% higher (480 to 530ppm). These increases in levels are observed immediately after the change of the ventilation conditions from impulsion to extraction, but quickly stabilize and do not increase further with time.

2. Modifications of the air flow intensity. PMx concentrations are lower during summer when tunnel ventilation is stronger in order to maintain passenger comfort. This decrease is most obvious in stations fitted with platform screen door systems. Using the train piston effect alone (without additional mechanical ventilation in the tunnel) saves energy but raises ambient PM2.5 concentrations by around 29%. Narrow platforms with single-track tunnels are especially dependent on forced tunnel ventilation to maintain relatively low PM concentrations.

3. Modification of air conditioning inside trains. Air quality inside trains is better than in the platforms. The use of air conditioning results in a clear drop in PM concentrations inside the carriages, especially with regard to coarser inhalable particles, with average concentrations being 47% lower when air conditioning was operating. No obvious change in air quality with time was observed during the use of the same air conditioning filter for three months, offering the potential for cost savings in filter replacement protocols. Wherever possible, experimental data should be presented with uncertainty/error bounds and a statement of how these bounds were determined should be presented.

4 CONCLUSIONS
Air ventilation is one of the key factors influencing the air quality in the subway systems. Any modification on the protocol should be carefully designed, as changes in ventilation power or direction can lead to drastic increases on concentrations of air pollutants from the moment of change. Also trains equipped with air conditioning systems have a cleaner air than the platforms and therefore studies on efficiency of air conditioning filters are needed. The detailed study of the parameters influencing air quality in a large number of stations within the IMPROVE LIFE project is leading us to develop protocols aimed at producing discernible improvements to rail subway air quality.

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