Real-driving measurement of in-vehicle air quality and particle filtration

Yingying Cha
Contact: yingying.cha@cabinair.com
CabinAir Sweden AB
Objectives

The objectives are:

▪ To develop a mobile real-driving test method for in-vehicle air quality and cabin air filter's performance, suitable for fleet test, short-term and long-term test

▪ To evaluate the filtration performance of cabin air filters of different conditions in real-life driving environments
Data logger and sensors

CabinAir Data logger is a device to power and control sensor measurement, to collect, display and upload data

- Internal sensor module (PM, CO₂, tVOC, temperature & humidity)
- External sensor module (PM, temperature & humidity)

- Linux based embedded system
- Single Core 1GHz CPU
- 1GB RAM
- 2 Channel I2C
- 1 Channel LIN
- WIFI
- Bluetooth 4.1 & BLE
- 4G modem
- GPS (USB, optional)
- Amazon web services
Verification of PM sensors

Aerosol generator: Designed by Tsinghua University: Patent No. CN201210153212.4
Verification of PM sensors

NaCl aerosol

Reference instrument
Dust Trak model 8357
(0.3 – 10 µm)
Big deviation for the SBRK015 indoor sensor, acceptable performance for the rest sensors (intra-model variability <10%)

DEHS aerosol

Reference instrument
Grimm MiniWRAS 1.371
(10 nm – 35 µm)
Compare sensors’ performance to each other, intra-model variability <10%
Verification of CO$_2$ sensors

Good consistency of CO$_2$ sensors’ readings and LI-820
Boundary conditions

- Average outdoor PM2.5 concentration greater than 20 µg/m³
- Windows and doors are closed during the whole test
- HVAC ventilation: totally fresh air (CO₂ concentration less than 1000 ppm with less than 2 passengers)
- HVAC fan speed: Low or medium
- Continuous driving for at least 20 minutes
- No interior PM sources, e.g. smoking
Short-term test – overview

- Organizations: CabinAir, Tsinghua University
- Test time and location: May-July 2020, Beijing China
- Test vehicles: 5 recruited volunteer drivers (2 GM, 3 VW)
- Existing cabin air filters, 3 -12 months since installed
- Test method: city-road driving
- Driving routes: Usually between the drivers’ home and office in Beijing city
- Parameters measured: PM2.5 and CO₂
- Reference instrument: Dust trak II model 8357, LI-820

Cooperation partner: School of Environment, Tsinghua University
Test vehicles

Institute: CabinAir + Tsinghua University
Test method: real-driving tests
Test vehicles: 5 recruited vehicles (model year 2014-2020)
HVAC ventilation: fresh air

- 5 sets of Data logger units
- 5 indoor sensor modules (PM, CO₂, temp & humidity)
- 5 outdoor sensor modules (PM, temp & humidity)
- Similar location of sensors on different cars

GM Lacrosse  
VW Audi  
VW Teramont  
VW Golf  
GM Envision

Location of outdoor/indoor sensor modules
Test result – PM2.5 efficiency

<table>
<thead>
<tr>
<th>Cabin air cleaning solutions</th>
<th>Number of validated tests</th>
<th>PM2.5 removal efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing filters</td>
<td>6</td>
<td>40%</td>
</tr>
<tr>
<td>New original OEM filter</td>
<td>5</td>
<td>80%</td>
</tr>
<tr>
<td>CabinAir Nordzone filter</td>
<td>7</td>
<td>84%</td>
</tr>
<tr>
<td>CabinAir Nordzone system</td>
<td>4</td>
<td>96%</td>
</tr>
</tbody>
</table>
Examples of in-cabin air quality

- Efficiency 41%: Existing filter
- Efficiency 82%: Newly installed original OEM filter
- Efficiency 95%: CabinAir Nordzone™ system
Recirculation and CO$_2$ increase

Recirculation was activated automatically on some vehicles even though it was set to be off in the beginning.

Number of passengers: 3
HVAC ventilation setting: recirculation off (confirmed by the driver)
Cabin air filter: Nordzone filter
Long-term test of vehicle filtration

CabinAir Advanced Air Cleaner solution:
Based on Blueair HEPASlient™ two-step technology (ionization + filtration)

Vehicle test in Shenzhen, China
Long-term performance

Location of test: Shenzhen
Driving time per day: > 60 min
No. of days with filter: 23
No. of days with AAC: 27

Original filter: OEM filter
Filter Installed: 2020-08-18
AAC installed: 2019-09-30

Vehicle settings
Ventilation: Fresh air
Fan speed: medium
Summary

1. The CabinAir mobile test method can be used for short-term, long-term, and fleet vehicle test for VIAQ and filter filtration performance evaluation
2. Boundary conditions are important to properly evaluate the performance of different cabin air cleaning solutions
3. CO$_2$ measurement should be done in parallel to avoid impact of recirculation
4. Aged filters (>3 months used) can filter out 20-50% small particles
5. Ionization technology can significantly improve the PM2.5 efficiencies of both new and aged filters