2019-08-05

Draft

Project Plan for the CEN Workshop on real drive test method for collecting vehicle in-cabin pollutant data (CEN/WS 103)

Workshop

(to be approved during the Kick-off meeting on 2019-11-04)

1. Status of the Project Plan

Draft Project Plan to be to be approved at the Kick-off meeting of the Workshop.

2. Background to the Workshop

2.1 Context of in-cabin regulations and standards

Particles and carbon dioxide exposure are not regulated inside the vehicle cabin, even though they are at the tailpipe. This is despite the increasingly well understood link between particle exposure and respiratory and other health effects, and the tendency of CO_2 exposure to lead to cognitive impairment at elevated concentrations.

Cabin air quality is not just about comfort, but also safety. High levels of cabin carbon dioxide are associated with stale air, but also it is a sign of cognitive effects that might lead to increased reaction times and drowsiness. Particles not only can smell bad, but exposure to them is often associated with chronic health effects and increased morbidity.

In contrast to tailpipe emissions, vehicle interior air quality is lightly regulated. Nevertheless, in the broad area, there are existing ISO and SAE standards, and an active United Nations Economic Commission for Europe (UNECE) working group. Some countries have national standards, in particular Korea, China and Russia.

Volatile organic compounds (VOCs) are the focus of ISO 12219-1:2012: "Interior air of road vehicles - Part 1: Whole vehicle test chamber – Specification and method for the determination of volatile organic compounds in cabin interiors".

A sample of the most relevant SAE technical papers is:

- 2008-01-0829 – Field Tests to Monitor Build-up of Carbon Dioxide in Vehicle Cabin with AC System Operating in Recirculation Mode for Improving Cabin IAQ and Safety

- 2009-01-3080 – Field Monitoring of Carbon Dioxide in Vehicle Cabin to Monitor Indoor Air Quality and Safety in Foot and Defrost Modes

- 2016-01-0254– Experimental Investigation to Determine Influence of Build-up of Cabin Carbon Dioxide Concentrations for Occupants Fatigue

- 2017-01-0163 – Development of a Model to Predict Build-Up of Cabin Carbon Dioxide Concentrations in Automobiles for Indoor Air Quality

- 2017-01-0169 – The Impact of Increased Air Recirculation on Interior Cabin Air Quality.

In addition, the SAE has relevant committed in the VOC Committee and Interior Exhaust Gas Committee.

The UNECE has a working party on pollution and energy (GRPE), covering the subject of on Vehicles Interior Air Quality (VIAQ) – GRPE-76-35. The original mandate of the group ran until November 2017, and it concluded with the tabling of a proposal for a new Mutual Resolution on recommendations to harmonize test procedures of interior air emissions generated from interior materials (ECE/TRANS/WP.29/2017/136) which was adopted by WP.29 and AC.3 during 173rd WP.29 session in Geneva (14-17 November 2017). The mandate of the working part was then extended until November 2020 in order to extend the work and consider not only emissions generated by interior materials, but also gases from other sources that enter the vehicle cabin. The terms of reference for this second stage are:

- Identify and collect the information and research data on interior air quality and its relevance for vehicles, taking into account the activities being carried out by various governments, and non-governmental organisations.

- Identify and understand the current regulatory requirements with respect to vehicle interior air quality in different markets.

- Identify, review and assess existing test procedures suitable for the measurement of harmful substance into the vehicle cabin (including test modes, sample collection methods and analysis methods, etc.)

- Develop provisions and test procedures in a recommendation by including Part 3 in the Mutual Resolution No. 3.

The current substances that it has been agreed to measure under this working group are:

- Carbon monoxide (CO)

- Nitrogen oxide (NO)

- Nitrogen dioxide (NO_2)

- Formaldehyde (CH_2O)

- Methane CH_4 (for natural gas vehicles only).

In additional, particulate matter (PM) may be included.

Beyond this, the Russian standard also covers Saturated hydrocarbons (C_2H_6…C_7H_{16}).

In Korea, the Automobile Management Act Article 33_3 of 18 December 2012 sets down rules for the 'Indoor air quality management for newly produced vehicles', while the Ministry of Land, Infrastructure and Transport Announcement No. 2007_539, 5 June 2007 gives "Indoor air quality management guideline for newly produced vehicles" which sets out emissions limits for seven specific VOCs, including formaldehyde, benzene, toluene, ethyl benzene, xylene, styrene and acrolein.

In China, standards started with HJ/T 400_07 December 2007 "Determination of Volatile Organic Compounds and Carbonyl Compounds in Cabins of Vehicles" and GB/T 27630-2011 01 March 2012 "Guideline for air quality assessment of Passenger car", issued by China's Ministry of Environmental Protection and State Administration of Quality Supervision, Inspection and Quarantine. The VOCs covered were the same as for Korea, with the addition of acetaldehyde, and the procedure has been developed since then.

In Russia, test methods and regulations have gone beyond VOC emissions from interior materials to include vehicle exhaust gases found in the vehicle interior air during driving. The national standard GOST R 51206, "Pollutant Contents in the Air of Passenger Compartment and Driver's Cab", was developed in 2004 to set limits for combustion gases and certain VOCs idling and while operating the vehicle at 50 kph.

2.2. Overview of health effects

The World Health Organisation (WHO) has found no 'safe' lower limit for particle pollution. The ideal level of airborne particle pollution is zero.[1] In a US context, this conclusion was recently amplified by a landmark study of 61 million Americans over seven years, published in the *New England Journal of Medicine* in 2017.[2] The authors found that even at levels *below* the lower limit (12 µg/m3, expressed an annual mean) for fine particulate matter (PM 2.5) mandated by the Environmental Protection Agency (EPA) within its National Ambient Air Quality Standard (NAAQS), they continued to observe "significant associations between exposure and mortality." In other words, the relationship between particle pollution and human health appears to operate right up and down the scale, confirming the stance taken by the World Health Organisation that there is no safe lower limit.

WHO estimates that 7 million deaths are caused each year globally by exposure to fine particles in polluted air that penetrate deep into the lungs and cardiovascular system, causing diseases including stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and

[1] https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-healthThe relevant section reads: 'Small particulate pollution have health impacts even at very low concentrations – indeed no threshold has been identified below which no damage to health is observed. Therefore, the WHO 2005 guideline limits aimed to achieve the lowest concentrations of PM possible.'

[2] 'Air Pollution and Mortality in the Medicare Population', by Di, Q, Wang Y, Zanobetti A, et al. *New England Journal of Medicine*, Vol 376:26 (July 2017) 2513-2513.

respiratory infections, including pneumonia. Nine out of ten of these deaths occur in low- and middle-income countries outside the USA, and often from domestic sources such as open fires used for cooking. *New England Journal of Medicine* article, the authors observed that "each increase of 10 micrograms per cubic meter in annual exposure to PM 2.5 (estimated independently of ozone) … was associated with an increase in all-cause mortality of 7.3%." Transport and traffic remain a major source of particle pollution, whether from combustion of diesel and gasoline or from non-tailpipe sources such as tyres abrasion, brake wear, road wear and re-suspension of particles and other debris on the roadway.

Two important findings came out of the Six Cities study. First, the importance of particle size as opposed to just particle mass (weight). Fine particles, they concluded, were more harmful than coarse particles because more difficult for the body to expel. Second, that these same fine particles penetrate indoors, "resulting in strong correlations between indoor and outdoor concentrations." It is no exaggeration to say that much of the research that has followed on the epidemiology of air quality has been preoccupied with these twin themes: ingress to buildings and, more recently, vehicle interiors, plus the increased harm potential of fine or ultrafine particles.[3]

In one formative study in 1996 it was suggested by the Scottish researcher Anthony Seaton that inflammation caused by the 'clean-up' might trigger the body's immune systems, add to blood clotting and thereby increase the risk of heart attacks and strokes.[4] Other studies have considered increased blood pressure and other stressors of the body and its major organs. The current worry concerns ultrafine particles that have been shown to translocate through the lungs into the bloodstream, after being breathed in.[5]

Motor vehicles are the dominant source of oxides of nitrogen (NO_x), particulate matter (PM), and certain air toxics (e.g., benzene, 1,3-butadiene) in urban areas. On roadways, motor vehicle-related pollutant concentrations are typically many times higher than ambient concentrations. The ingress of ambient air to in-cabin has been noted in several studies, the concern being that concentrations may rise inside certain vehicles, to the point where it is higher than outside, affecting drivers and occupants more than pedestrians and cyclists, although the evidence is not conclusive in this regard.[6]

In a recent paper focused on Los Angeles, the authors concluded: "Our analysis demonstrated that on freeways, concentrations of ultrafine particles (UFPs), black carbon, nitric oxide, and PM-bound polycyclic aromatic hydrocarbons (PM-PAH) are generated primarily by diesel-powered vehicles, despite the relatively low fraction (6%) of diesel-powered vehicles on Los Angeles

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[3] Particles of 10 micrometers (µm) in diameter and below are referred to as PM10. One micrometer is one-millionth of a metre, or one-thousandth of a millimetre. Particles of 2.5µm to 0.1 µm are referred to as PM2.5 – this is the measurement of fine particles. Particles below 0.1 µm are referred to as ultrafines (UF) and are measured on the nanoscale down to 0.015 µm or below.

[4] Seaton, A., 'Particles in the air: the enigma of urban air pollution.' *Journal of the Royal Society of Medicine,* Vol. 89 (11), 604-7.

[5] Devlin, Robert B. 'Controlled Exposure of Humans with Metabolic Syndrome to Concentrated Ultrafine Ambient Particulate Matter Causes Cardiovascular Effects'. *Toxicological Sciences* Vol. 140:1, 61.

[6] Weichenthal, S.; Dufresne, A.; Infante-Rivard, C.; Joseph, L. 'Determinants of ultrafine particle exposures in transportation environments: findings of an 8-month survey conducted in Montreal, Canada.' *Journal of exposure science & environmental epidemiology*. Vol 18:6, 2008, 551-563.

freeways. However, ultrafine particle concentrations on arterial roads appeared to be driven primarily by proximity to gasoline-powered vehicles undergoing hard accelerations."[7]

A study in 2014 notes, "ultrafine PM which comprises the smallest fraction of fine PM (aerodynamic diameter <0.1 μm) may be disproportionately toxic relative to the 0.1–2.5 μm fraction. Ultrafine PM is not routinely measured in state monitoring networks and is not homogenously dispersed throughout an airshed but rather located in hot spots such as near combustion sources (e.g., roads)."[8]

In another study focussing on US citizens with metabolic syndrome, the authors noted "changes in markers of blood inflammation and fibrinolysis as well as changes in heart rate variability and cardiac repolarization." They concluded, "This controlled human exposure study is the first to show that ambient ultrafine particles can cause cardiovascular changes in people with metabolic syndrome, which affects nearly a quarter of the U.S. adult population."[9]

Another study found "statistically significant associations between elevated ultrafine particle (UFP; diameter: 0.01–0.1μm) and total as well as cardio-respiratory mortality, each with a 4 days lag." Finally, another study suggests that evidence has been found for a difference between how the body reacts to fine particulates at the PM2.5 level, and ultrafine particulates at the nanoscale: "The results suggest that the cardiovascular effects of ambient ultrafine and PM2.5 can differ from each other and that their effect may be modified by the characteristics of the exposed subjects and the sources of PM2.5."[10]

CO_2 has a direct relationship with drowsy driving which leads to traffic accidents. In a confined space CO_2, which we are used to discussing typically as a 'greenhouse gas,' becomes a noxious pollutant in confined space, of immediate consequence for human health. We are not accustomed to thinking of CO_2 as a pollutant. This is because CO_2 is the fourth most abundant gas in the earth's atmosphere. At room temperature, it is a colourless, odourless, non-flammable gas, at other temperatures and pressures, carbon dioxide can be a liquid or a solid. Carbon dioxide is a by-product of normal cell function when it is breathed out of the body. Background CO_2 is typically ~400ppm. Measured background CO_2 around roads is typically slightly higher at 450-500ppm

Cognitive impairment starts around 1000ppm, resulting in drowsiness. At the 2-5,000ppm band, headaches and sleepiness result from stagnant, stuffy air. Other leading symptoms will be poor concentration, loss of attention, increased heart rate and nausea. Testing has shown that CO_2 inside vehicles will typically reach 2500-4000ppm with the re-circulation function deployed. The 5,000ppm level in a workplace situation may indicate the presence of other gases and is

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[7] Author: Fruin, S.; Westerdahl, D.; Sax, T.; Sioutas, C.; Fine, P. M.; 'Measurements and predictors of on-road ultrafine particle concentrations and associated pollutants in Los Angeles.' *Atmospheric environment*. Vol 42:2, (2008), 207-219.

[8] *Ibid.*

[9] Ljungman adult population Petter L. et al., 'The Impact of Multipollutant Clusters on the Association Between Fine Particulate Air Pollution and Microvascular Function'. *Epidemiology*. Vol. 27:2 (2016).

[10] Timonen, K. L., et al. 'Effects of ultrafine and fine particulate and gaseous air pollution on cardiac autonomic control in subjects with coronary artery disease: The ULTRA study.' *Journal of exposure science & environmental epidemiology*. Vol. 16:4 (2006) 332-341.

considered to be unusual or of short duration. At 40,000ppm oxygen deprivation results in immediate harm.

Many vehicles count as workplaces and are subject to legal or regulatory criteria. In this sense they are comparable to offices. In a landmark paper concerning indoor air quality in offices, the authors conducted experiments to determine the health impacts of environmental factors such as humidity, building factors such as ventilation, and workspace factors such as chemical-emitting materials. They also studied CO_2 as a direct pollutant. They found in summary that worker cognitive function was 63 to 101% higher in buildings with superior ventilation. Broken down across nine categories of cognitive function, all but two showed average cognitive scores decreasing at each higher level of CO_2.[11]

2.3 Need for public real-world emissions data

“Ambient air quality is a growing concern especially near roadways in large metropolitan areas. As congestion rises and people spend more time in their vehicles, in-cabin air quality is becoming a real concern. Near-roadway pollutants increase a person’s exposure to unhealthy air which includes high levels of particle number both of which are associated with health effects and chronic illnesses. Many solve this problem by turning on recirculation, but then higher amounts of CO_2 fill the cabin space in tens of minutes. This can cause drowsiness if one is exposed to high concentrations for hours, which, from some of the data I have seen, may be present in the vehicle. The approach of the air quality index is a great example of public attention and industry response without a complex and costly regulation system.”

Kent Johnson, Ph.D.
Principal Investigator, Emissions and Fuels Research
College of Engineering - Center for Environmental Research and Technology
University of California, Riverside

The propose work under this Project Plan is complementary to the work of the SAE and UNECE VIAQ group.

The consumer and public health need addressed by this Project Plan is in-cabin CO_2 and particle number concentrations, and proposes a method for gathering data in real, on-road driving, with other vehicles and pollution sources in the vicinity. This is not intended to provide a pass/fair certification methodology, but rather a tool that guide buyer demand and supplier quality.

Guiding driver behaviour post-purchase is also relevant. A driver choice is whether the ventilation system should be set to fresh-air or recirculation mode – each of which have effects and trade-offs in the relative concentrations of CO_2 and particulates. A survey in 2011 in Korea showed the following usage and preferences around these two modes:

[11] Allen JG, MacNaughton P, Satish U, Santanam S, Vallarino J, Spengler JD. *Environmental Health Perspectives* 124:6, 2016, 802-812.

Driving type	Recirculation mode	Refresh mode	Don’t care
City	57%	32%	11%
Highway	49%	39%	12%

Source: Korean Ministry of Land, Infrastructure and Transport (MOLIT) and Korea Automobile Testing & Research Institute (KATRI)

The context to this is that many European cities are in breach of PM ambient air quality standards[12] that became legal limit values in 2010, although the numbers are falling. Nevertheless, the in-cabin exposure to particulates is more directly determined by vehicles in the immediate vicinity. For example, if you are driving behind a pre-2009 diesel car – with no particulate filter – it is likely that a large number of particles will enter the vehicle cabin, even if on average the PM concentrations across the wider area are low. To protect from this, drivers sometimes use the recirculation mode, but the interior CO_2 then rises quickly, to a point that increases driver safety and comfort.

Data from Emissions Analytics evidence these points. Figure 1 shows the relative particle concentrations inside and outside of a typical vehicle in each of the HVAC modes.

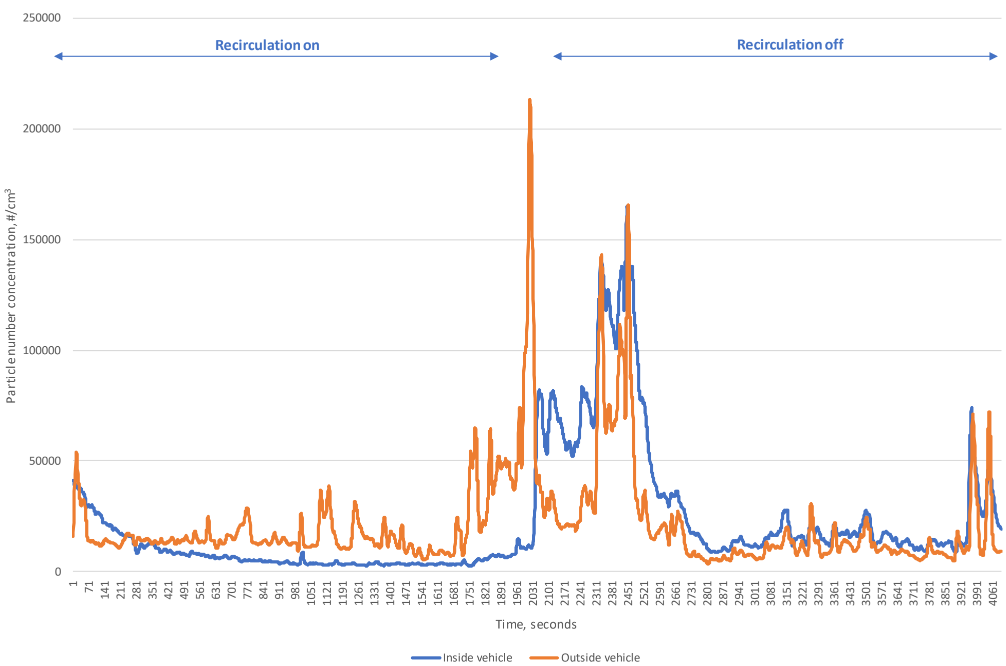

Figure 1: PN concentrations simultaneously inside and outside the cabin

[12] Directive 2008/50/EC http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0050

When in the recirculation mode, the internal CO_2 on the same vehicle was as shown in Figure 2. Cognitive effects can be seen above 1,000ppm.

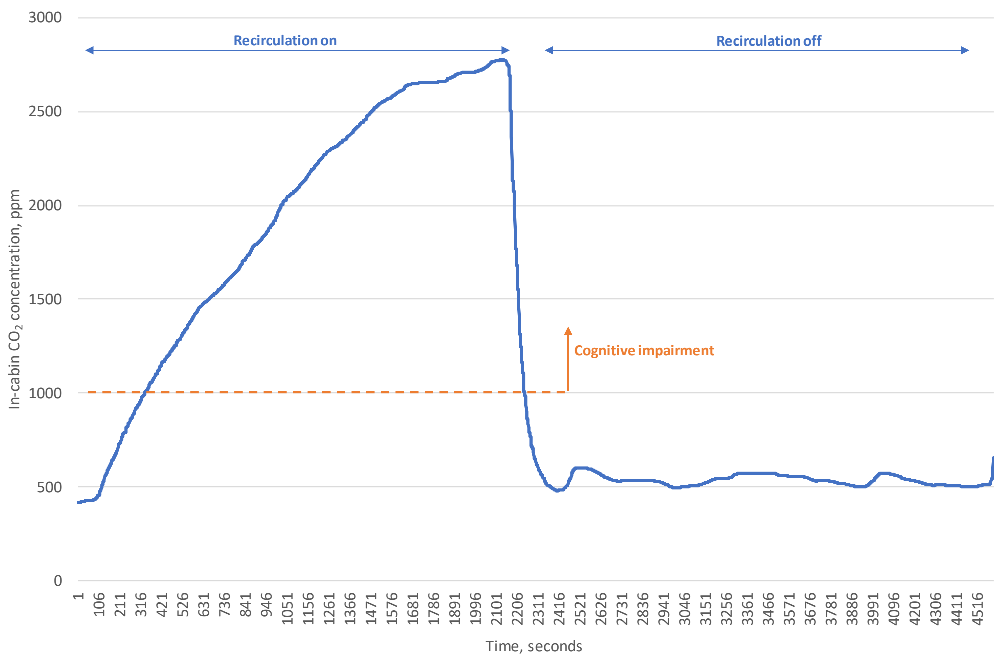

Figure 2: CO_2 build-up with recirculation mode on and off

The data above uses a constant fan speed. However, this is a further choice for the driver, and which influences interior air quality. The table below shows the differential performance on a typical vehicle.

HVAC setting	**PN reduction**	**CO_2 reduction**
Low fan, AC/recirc off	53%	18%
Medium fan, AC/recirc off	65%	24%
High fan, AC/recirc off	71%	28%
Medium fan, AC/recirc on	45%	0%

Source: Emissions Analytics

The essential components of the proposed methodology are that testing is undertaken on the public highway, sampling simultaneously outside and inside the vehicle, with the ratio of the two calculated in order to calculate a standardised metric for particle ingress. It is proposed that the ingress rate is independent of absolute ambient concentrations, within certain boundaries.

Traffic flows and congestion can affect the ambient pollution immediately around the test vehicle, but the proportion of particles that enter the cabin remain in a relatively constant ratio.

The concept is to standardise the method for collecting vehicle in-cabin air quality data. The ratings themselves would be outside of scope. The data collected should measure how well the vehicle filters out particles from air coming in, and how well the ventilation system keeps the cabin air fresh.

Simultaneously with measuring particle number, CO_2 would also be measured, both at around 1Hz. While external CO_2 would be measured, the primary interest would be in the inter-temporal trend internally.

In order to isolate the ventilation system's ability to clean up high PN and CO_2 concentrations already present in the cabin, the air exchange rate is measured by a static test in controlled conditions. This could involve venting the cabin to align it with background concentrations, and then introducing CO_2 (using a small CO_2 canister), which due to contamination also releases a large number of particles. Immediately on introduction, the vehicle cabin is sealed, and the pollution concentrations are measured until they return to near background concentrations.

Key criteria in validating the methodology would be the repeatability, reproducibility and efficiency of the process.

The motivation for this CEN workshop is therefore to define a method that would allow comparison of the real-world emissions of vehicles under the same conditions of use. This would allow manufacturers and consumers to specify the best ventilation systems to reduce health exposures and maximise safety and comfort. The method should prescribe protocols for implementation steps such that the emissions test result is robust to implementation by different operators

2.4 Benefits to consumers and policy makers

The existence of a comparative data may lead to many benefits such as:

- Reducing the ingress of pollution while simultaneously mitigating the build-up of CO_2, but OEMs specifying the most effective filters
- Installation of more effective filters in the aftermarket
- Acceleration commercialisation of 'high-efficiency cabin air filters' have the capacity to greatly reduce infiltration to the cabin of particle matter including down to the ultrafine level, at stationary, urban and highway driving speeds. In one study of twelve different vehicles conducted in Los Angeles, not only did high-efficiency (HECA) filters achieve 2-3 times greater reduction of particle infiltration than OEM filters, and up to a 99% reduction, but they performed particularly well against ultrafine particles
- Reduction of health disbenefits associated with particle exposure
- Reduced incidence of accidents due to cognitive impairment
- Increased comfort for drivers.

3. Workshop proposers and Workshop participants

The proposer of this CEN Workshop is the AIR Alliance (Allow Independent Road-testing Company Ltd), a global not-for-profit organisation (www.allowair.org) which empowers car buyers and policy makers with the ability to reduce vehicle emissions and improve air quality by providing an independent, trusted, on-road vehicle emissions ratings for cars.

AIR was formed in 2017 is an alliance of scientists, health regulatory experts, people and organisations committed to addressing emissions and health exposures from vehicles.

AIR was created to cut through the politics, the controversy and the commercial conflict to deliver trusted information based on the collective scientific experience and knowledge of the world's leading experts in air quality and healthcare.

Without reliable and independent information it is likely that that poor consumer and policy decisions will be made, that will in turn cause air quality in our towns and cities to deteriorate, and increase the population's exposure to such pollution. The AIR Alliance is a platform to work together to achieve the right solution to reduce the negative impacts of vehicle emissions.

Potential interested stakeholders to be involved in this CEN/WS are: car makers, filter material makers, HVAC systems manufacturers, test equipment manufacturers, test laboratories, consumers, health experts, policy makers, universities and research institutions, environmental NGOs.

Workshop scope and objectives

The CEN/WS intends to develop a CWA (CEN Workshop Agreement) which will define a standard test procedure that can be used to collect test data for in cabin air, for different vehicles makes and models.

In particular, the CWA will specify a standardised on road test procedure for real world in cabin air which measures how well the vehicle filters out particles from air coming in, and how well the ventilation system keeps the cabin air fresh.

The resulting CWA is covered by copyright and the exploitation rights are with CEN.

4. Workshop programme

CEN/WS official langue will be English. The CWA will be in English.

Three versions of the CWA will be produced during the CEN Workshop: first draft, one intermediate version, and a final version, according to the following milestones (dates and meeting places are tentative and subjected to confirmation).

CEN Workshop participants will decide at a later stage during the development of the CWA if the document will be submitted also to the public commenting phase of 60 days.

Tentative Time-plan*

Description	Time	Place	Duration
Announcement of the CEN/WS on CEN website	End of August 2019	CCMC	30 days' notice
CEN/WS Kick Off of Workshop	5th November 2019	Brussels	1 day
Collection of inputs for the drafting of the first Draft content CWA	January 2019	N/A	
CEN/WS 1st Plenary Meeting	February 2020	TBD	1 day
1st Draft of the CWA deliverable	March 2020	N/A	N/A
Circulation of 1st Draft CWA and collection of comments	May 2020	N/A	2 months
CEN/WS 2nd Plenary Meeting	June 2020	TBD	1 day
Circulation of 2nd Draft CWA and collection of comments	August 2020	N/A	1 month
CEN/WS 3rd Plenary meeting and decision on next steps	September 2020	TBD	1 day
Circulation of 3rd Draft CWA	October 2020	N/A	1 month
CEN/WS 4rd Plenary meeting and decision on next steps	November 2020	TBD	1 day
Circulation of final 4th Draft CWA	November 2020	N/A	1 month
Publication of CWA deliverable after editorial check	December 2020/January 2021	UNI/CCMC	2 months
* The Time-plan is subjected to be modified in relation to the drafting process of the CWA and to the eventual decision on the submission of the document to 60-days commenting phase.			

5. Workshop structure

The Workshop proposers suggest the following Workshop structure that has to be approved during the Workshop Kick-Off meeting:

Chair: Nick Molden (AIR Alliance)

Main responsibilities:

- To preside at the Workshop plenary meetings
- To ensure that the Workshop delivers in lines with its Business plan;
- To manage the consensus building process
- To interface with CEN/WS Secretariat and CEN Management Centre regarding strategic indications, problems arising in the development of the CWA

Secretariat: Elena Mocchio (UNI – Italian National Standard Body)

Main responsibilities:

- To offer the infrastructure for electronic operation (i.e. Livelink platform);
- To administer the CEN Workshop's members list(s) and official registration of participants;
- To manage documents and their distribution, and to update the document register;
- To prepare and distribute CEN/WS Documents (i.e. draft agendas and information on meetings arrangements, minutes of the meetings, draft CWAs, etc.);
- To chase actions as decided by the CEN Workshop meeting;
- To advise on the requirements of the CEN/CENELEC Internal Regulations and decisions of the CEN/CA and CEN/BT in the development of a CWA;
- To provide expertise in standardization and provide relevant standards to the Workshop, when or where necessary;
- To check conformity of all of the versions of the draft CEN Workshop Agreement to CEN rules;
- To initiate and manage the CWA approval process, upon decision by the Chairman;
- To record expression of support to the CWA for transmission to the CEN Management Centre;
- To participate to CEN Workshop plenary meetings, audioconferences and meetings with the Chairman.

6. Resource requirements

The registration and participation at this CEN Workshop are free of charge for every member of the Workshop, but each participant will bear his/her own costs for travel and subsistence.

The administrative costs of the Workshop Secretariat and other logistical support will be covered by the AIR Alliance.

7. Related activities, liaisons, etc.

Although the CWA does not address any issue specifically covered by a CEN/TC, the work carried out by the CEN/WS may be of some interest for CEN/TC 264 *Air quality* and CEN/TC 301 *Road vehicles*.

8. Contact points

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