MEASUREMENT OF ROAD TUNNEL AIR QUALITY - EN 50545-2

Dr Fathi Tarada

mosen

Motivation

- There is currently no European standard for the performance and type testing of air quality sensors for road tunnels
- CENELEC working group CLC/TC/TC216/WG5 has been working for two years to address this issue

Contents

- Background
- Current status of air quality measurements
- Laboratory testing
- Field testing
- Available technologies
- Relationship to new ISO standard

Background

- 2006: Spanish National Committee of CENELEC committee TC 216 started a Vilamoura process in order to write a harmonized standard for carbon monoxide (CO) gas detectors in underground car parks
- Work finalised in 2011 with the publication of European EN 50545-1 standard

New Standard

- EN 50545-2: “General performance requirements and test methods for gaseous and airborne pollution measurements in tunnels”
- Functionality and performance of toxic gas detection and visibility measuring devices

mosen

CENELEC working group CLC/TC/TC216/WG5

13 experts from seven European countries:

• Thomas Halbach	(convenor, Spain)	Manufacturer
• Colin Edge	UK	Manufacturer
• Kai Einecke	Germany	Manufacturer
• Richard Hallam	UK	Manufacturer
• John Saffell	UK	Manufacturer
• Christoph Seewald	Germany	Manufacturer
• Bruno Vidal	France	Research institute
• Karl Wiesinger	Austria	Manufacturer
• Serge Adami	France	Manufacturer
• Fathi Tarada	UK	Consultant
• Christian Kuhn	Germany	Manufacturer
• René Jung	Austria	Manufacturer
• Marc Achermann	Switzerland	Manufacturer

mosen

Status of Tunnel Air Quality

- Carbon monoxide (CO) concentrations have fallen sharply Visibility levels have also improved and levels are generally lower than 2 km-1.
- Nitrogen monoxide (NO) concentrations are generally less than 5 ppm or can rise to 10 ppm in certain tunnels depending on the proportion of heavy goods vehicles.
- The most critical pollutant in road tunnels is nitrogen dioxide (NO_2). Concentrations of NO_2 observed are a few hundred ppb (200 to 400 ppb generally) when traffic flows smoothly in heavy traffic urban tunnels. In situations with traffic congestion, these concentrations can increase up to values of 2 ppm or more.

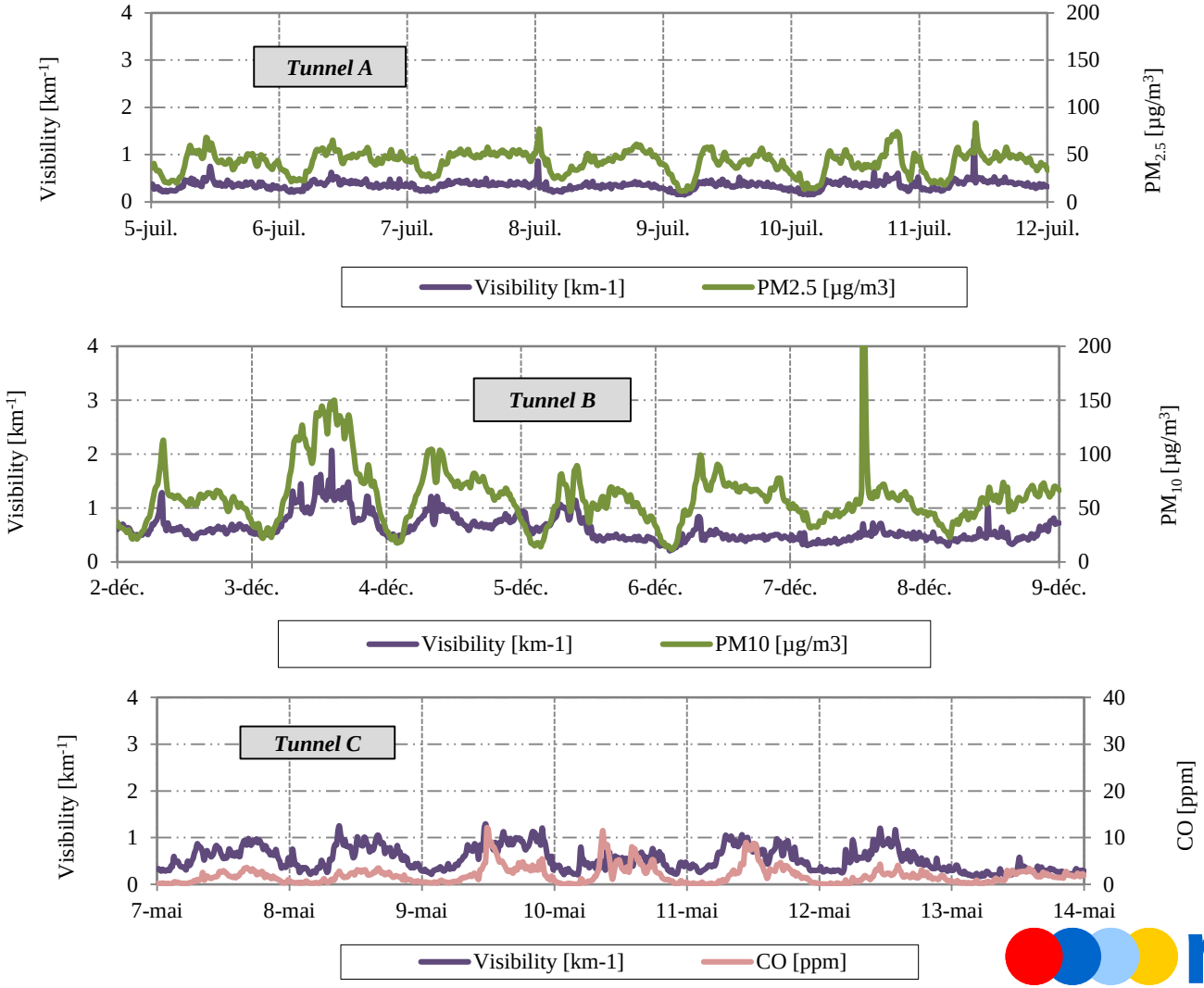
mosen

Example Measurements

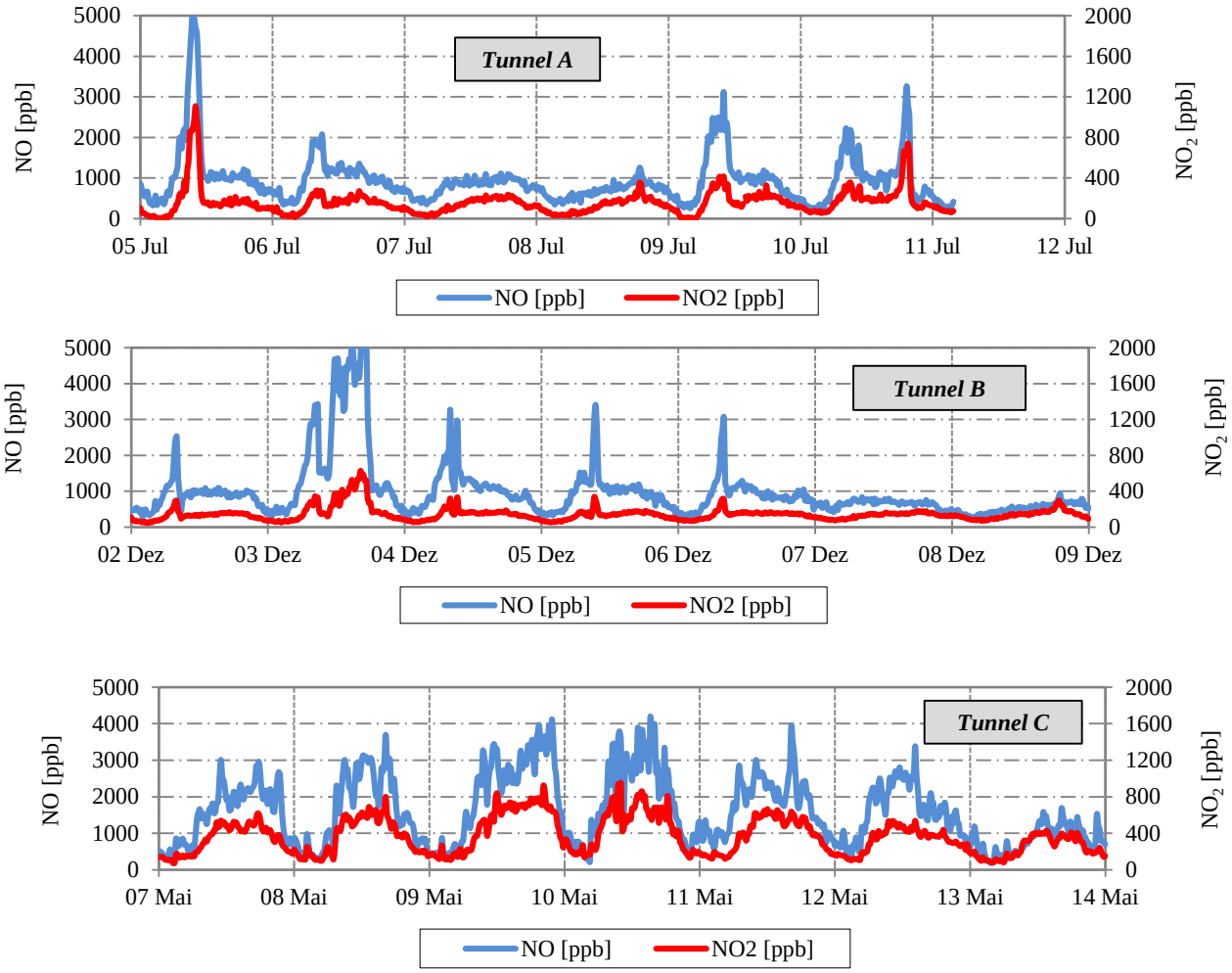
Tunnel	A	B	C
Type	urban tunnel / one way	urban tunnel / one way	Alpine tunnel / two-way
Traffic	35 000 vehicles/day 11% HGV	65 000 vehicles/day 13% HGV	5 000 vehicles/day 50% HGV
Tunnel length [distance from the entrance portal]	4 km [1.2 km]	6 km [0.4 km]	>10 km [0.6 km]
NO/NO_2 monitor	HORIBA APNA 370 or ThermoFisher 42 i CLD (Chemiluminescence)		
CO monitor	Alphasense electrochemical cell		
Opacity monitor	SIGRIST Visguard (based on scattered light intensity measurement)		
PM_{10} and $PM_{2.5}$ monitor	ThermoFisher TEOM 1400ab (Tapered Element Oscillating MicroBalance)		

mosen

CO, PM10 and PM2.5 concentrations and visibility levels



NO and NO_2 concentration measurements



mosen

Ventilation Control

- Improvement in air quality through dilution ventilation strategy.
- High energy consumption and negative environmental impacts.
- Accurate pollution sensors required to reliably and sustainably monitor air quality in their tunnels in real time.

mosen

Laboratory Testing - 1

- Extensive tests within the framework of EN50545-2 to significantly increase the confidence that buyers can have in these measuring instruments.
- 15 different descriptions of laboratory tests listed in the standard, including verifications of warm-up time, response times, linearity and repeatability tests, tests of cross-sensitivities and other tests which check the impact of varying ambient conditions such as temperature, humidity, etc.

Laboratory Testing - 2

- Separate test procedures and devices for gas and visibility measurements.
- For gas measurements, the lab tests are carried out mainly by applying different gas concentrations.
- For visibility measurements, the standard introduces the use of a base calibration. This base calibration must take into account the light spectrum in the tunnel and the particle size distribution in road tunnels. For transmission-based instruments, the standard proposes neutral density filters and for scattered light monitors it proposes scattering plates.

Field Testing - 1

- Two instruments will be mounted in close proximity to each other in a road tunnel meeting predetermined conditions.
- The testing within the tunnel will allow relevant data for repeatability to be obtained (ensuring both systems work together) along with span drift, zero drift, the effect of temperature and any effects due to contamination build-ups.
- The instruments will be repeatedly exposed to calibration checks using protocol gas or interference filters without adjustment over a period of 3 to 6 months or longer.
- The maintenance interval is vital for tunnel operators.

mosen

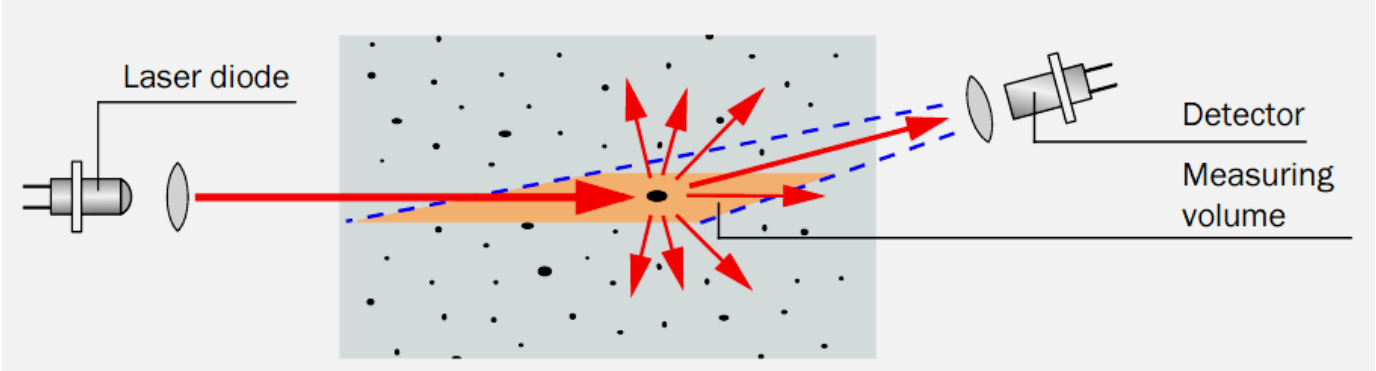
Field Testing - 2

- Finding such test tunnels can be a challenge for manufacturers and certification groups alike.
- This part of the certification process is designed to highlight strengths and weaknesses of the instruments and their resilience to the harsh environment of the road tunnel, giving tunnel operators the confidence that the instruments they use have been proven.

Measurement Technologies

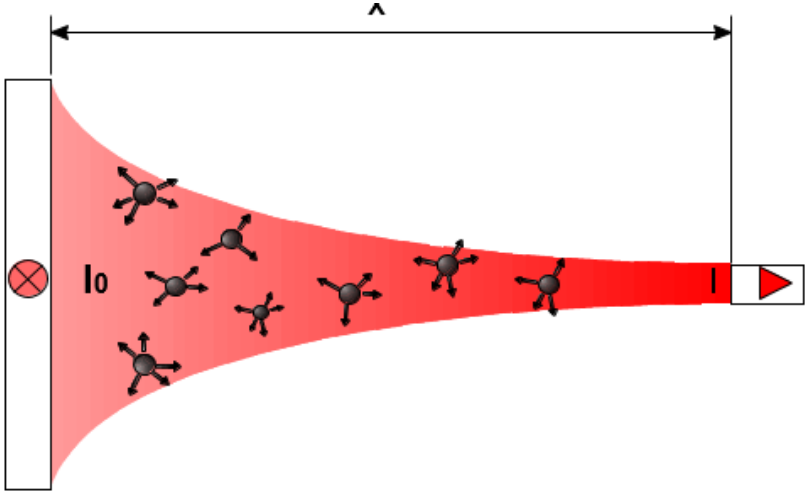
- The new standard has been written to include as wide a range of existing measurement technologies as possible.
- New technologies can be readily adopted, enhancing innovation and reducing costs over time.

Scattered Light Monitors



- When an electromagnetic light wave hits a particle, a certain amount of light gets scattered.
- Scattered light monitors have a linear response to the number of particles in the tunnel air, and thus provide a measurement of visibility.

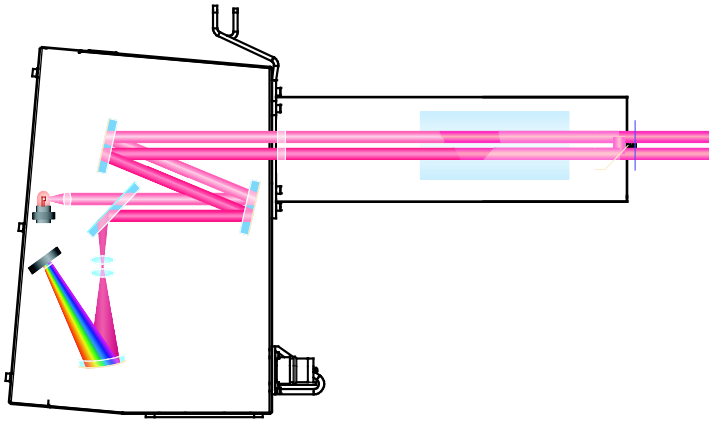
Transmission-based instruments



- Transmission based instruments measure the attenuation of emitted light over a certain distance. Following the Beer-Lambert Law, the transmission value has a non-linear behaviour with respect to dust concentration.
- Therefore the measurement of the light attenuation can be used as an indicator of visibility in road tunnels.

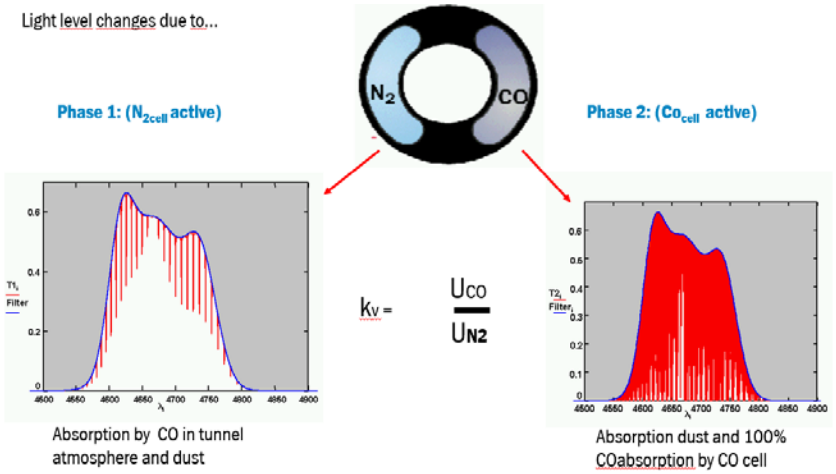
Gas measurements – differential optical absorption spectroscopy (DOAS)

- Light is emitted from a sender or a lamp, travels through a measuring distance, and then encounters a receiver.
- The receiver splits the light into a spectrum. This enables the detection of how much energy is absorbed at which wavelength by the gases that are present.



Gas measurements – gas filter correlation

- Two gas filled cuvettes are mounted on a rotating disc. This passes through a beam of light alternately. The measurement cuvette is filled with nitrogen while the reference cuvette is filled with a sample of the gas to be measured.
- Infra-red light passes through the gas to be measured and the difference in absorbance is measured and provides a direct output of the gas concentration.



Electrochemical cells

- Compact, low-cost, and portable gas sensors. Electrochemical sensors have high potential for use in ambient air quality monitoring applications by virtue of their accuracy.
- Produce an electrical charge directly proportional to the amount a toxic gas they are exposed to which is in turn is measured by the instrument to give a relative concentration level.
- Require more upkeep than an optical device and are therefore typically designed such that maintenance work such as cell calibration and replacement is as quick and easy as possible.

mosen

New ISO 23431 “Measurement of Road Tunnel Air Quality”

- “This Standard describes methods for determining air speed and flow direction, carbon monoxide (CO), nitric oxide (NO) and nitrogen dioxide (NO2) concentrations and visibility in road tunnels using direct reading instruments. This Standard specifically excludes requirements relating to instrument conformance testing”.

ISO 23431

- The main aim of the ISO standard is to provide calibration and check procedures that can be used by road tunnel operators after the air quality monitoring equipment has been installed and commissioned in the road tunnel.
- The procedures and methods described in the ISO standard can be used as a quality control to ensure the ongoing correct operation of the monitoring instruments.

mosen

Comparison between Standards

- EN-50545-2 will help tunnel operators control the maintenance costs of in-tunnel air quality monitors, e.g. by removing the need to perform multi-point linearity testing in the tunnel.
- The standard also specifies in-tunnel field testing of the monitors, which will provide quantifiable information on the minimum maintenance interval.
- This will allow the correct maintenance schedules to be determined for the equipment being used, and not having to adopt the fixed timescales defined in the ISO standard.

mosen

Review

- Background
- Current status of air quality measurements
- Laboratory testing
- Field testing
- Available technologies
- Relationship to new ISO standard

Questions?

mosen