Intercomparison study of Magee Scientific Multi-Wavelength Thermal/Optical Carbon Analyzers

DRI 2015

DRI 2015 with Upgrade kit

DRI 2015 Series 2

for quantifying organic carbon (OC), elemental carbon (EC) and total carbon (TC)

Berkeley, Ljubljana April 2022

Introduction

Carbonaceous aerosols are a major component of particulate matter (PM) in the atmosphere. Their composition spans the range from 'Organic Carbon' (often denoted "OC"); to 'Black' or 'Elemental' Carbon (denoted "BC" or "EC").

The various components of carbonaceous aerosols adversely affect human health and contribute to climate change. For these reasons, both WHO and IPCC recommended in their 2021 reports that countries and regional authorities should systematically measure and characterize carbonaceous aerosols. Similarly, requirements for measuring EC and OC in PM2.5 have been included in the European Air Quality Directive.

Instruments manufactured by Aerosol under the Magee Scientific brand name measure various components of carbonaceous aerosols, including 'Black', 'Brown', and 'Total' carbon content. These instruments are rugged, reliable, and are suitable for use in every application from research laboratories to field projects to routine air-quality monitoring stations.

The Magee Scientific Multi-Wavelength Thermal/Optical Carbon Analyzer is a highly sophisticated laboratory instrument providing the most advanced and complete analysis of carbonaceous aerosol particles previously collected on filters: usually either from the atmosphere or directly from sources.

In a sequence of multiple temperature fractions, the Magee Scientific Multi-Wavelength Thermal/Optical Carbon Analyzer quantifies organic carbon (OC) and elemental carbon (EC, closely related to Black Carbon [BC]). It monitors both the optical transmittance and optical reflectance of the sample simultaneously at 7 wavelengths. These optical signals correct the thermal analysis for the effects of pyrolysis and allow for apportionment in terms of 'Brown' carbon, an indicator of biomass combustion.

VERSIONS OF MAGEE SCIENTIFIC MULTI-WAVELENGTH THERMAL/OPTICAL CARBON ANALYZER

DRI-2015

In production 2015 - 2021

DRI-2015 with upgrade kit

Upgrade kit in production from 2022

DRI-2015 Series 2

In production from 2022

The original model of the DRI-2015 analyzer was manufactured from 2015 to 2021, and delivered to laboratories in many locations across the globe. This instrument has provided scientists and air quality monitoring agencies with comprehensive data in studies and measurements related to air pollution and its sources, source apportionment, climate change, public and occupational health. Extensive scientific literature by J. C. Chow, L.-W. A. Chen, X. L. Wang, D. H. Lowenthal, R. Zimmermann, J. G. Watson and many others, reports on the characterization of the carbonaceous component of aerosol samples collected on filters.

The model DRI-2015 Series 2 was introduced in 2022 and offers major improvements in terms of reliability, operation, maintenance, state-of-the-art components and shorter analysis time; while maintaining class-leading performance for characterization of carbonaceous aerosols. Improvements in the Series 2 model include upgrades to the oxidation and sample oven system, CO_2 sensor, several mechanical and electronic components, and software.

The Upgrade Kit for DRI-2015 is a modification solution for users of the (initial) DRI-2015 model, and offers the improvements of the DRI-2015 Series 2.

Intent of Intercomparison Study

The intent of this Intercomparison Study is to show that the performance of the newly developed DRI-2015 Series 2 and DRI-2015 with Upgrade Kit for characterization of the carbonaceous component of aerosol samples collected on filters, is identical to that of the initial analyzer, model DRI-2015.

This report summarizes the main results of the equivalence intercomparison study of different DRI instruments. The following instruments were used:

- DRI 2015 reference unit (SN: DRI 114)
- DRI 2015 with upgrade kit (SN: DRI 110)
- DRI 2015 series 2 (SN: DRI2_001)

The DRI 2015 upgrade kit and the DRI 2015 series 2 were thoroughly compared with the reference DRI 2015 unit. In the study, 22 different samples were analyzed with 2 different thermal protocols.

The DRI-2015 Series 2 and DRI-2015 with Upgrade Kit, both passed the equivalence intercomparison.

Additionally, a DRI-2015 Series 2 instrument successfully participated in the ACTRIS inter-laboratory comparison in 2022.

Sampling campaign

Samples used in this intercomparison were taken from three different batches collected from ambient air, as described below.

S/N	Sample name	Additional description
1	SKYLAB_07/06/2021	SKYLAB PM10
2	SKYLAB_28/06/2021	SKYLAB PM10
3	SKYLAB_21/08/2021	SKYLAB PM10
4	SKYLAB_27/12/2021	SKYLAB PM10
5	SKYLAB_07/12/2021	SKYLAB PM10
6	SKYLAB_22/12/2021	SKYLAB PM10
7	SKYLAB_23/12/2021	SKYLAB PM10
8	SKYLAB_10/11/2021	SKYLAB PM10
9	SKYLAB_17/11/2021	SKYLAB PM10
10	SKYLAB_21/12/2021	SKYLAB PM10

11	SKYLAB_14/01/2022	SKYLAB PM10
12	SKYLAB_04/02/2022	SKYLAB PM10
13	SKYLAB_16/02/2022	SKYLAB PM10
14	FSH00229	FRESNO PM2.5
15	FSH00227	FRESNO PM2.5
16	FSH00230	FRESNO PM2.5
17	FSH00191	FRESNO PM2.5
18	ARSO 1.3.2017	ARSO PM2.5
19	ARSO 8.3.2017	ARSO PM2.5
20	ARSO 25.2.2017	ARSO PM2.5
21	ARSO 3.3.2017	ARSO PM2.5
22	ARSO 7.3.2017	ARSO PM2.5

SKYLAB samples

Samples were collected at the urban background air quality monitoring station of Aerosol Company (SkyLab) at 46.0715°N, 14.5020°E, elevation 302 m. PALL 150 mm quartz fiber filters (Tissuquartz-2500QAT-UP) and PM10 size-selective inlet were used. Samples were collected at a flow rate of 500 LPM.

ARSO samples

Samples were collected between 7 February and 10 March 2017 at the urban background air quality monitoring station of the Slovenian Environmental Agency (ARSO) at 46.0654°N, 14.5120°E, elevation 299 m. This sampling site and period of the year were selected to test the performance of the instrument in a complex environment characterized by various sources of carbonaceous aerosols (traffic, domestic heating, secondary organic) exhibiting strong temporal variability and a wide range of properties (OM/OC, OC-EC, volatility, etc.). During this period, the daily average measured TC concentrations ranged from 3 to 26 μg/m^3 (Rigler et al., 2020)

FRESNO samples

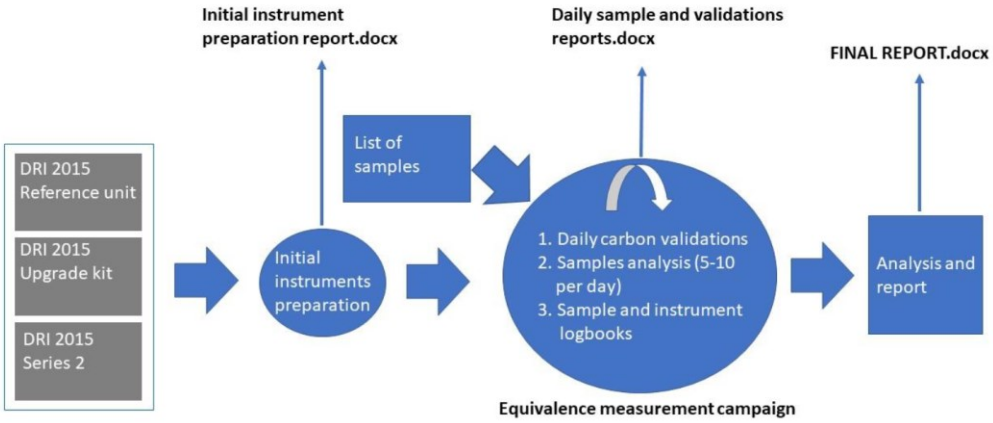
Ambient PM2.5 samples were collected on quartz-fiber filters (Pall Tissuquartz 2500QAT-UP) from the nonurban IMPROVE (Interagency Monitoring of Protected Visual Environments) visibility network; and an urban site in Fresno, California (Chow et al., 2009; Park et al., 2006).

Sample storage and handling

All sampled filters and field blanks were protected from external contamination during storage and transport. Filters were handled with clean tweezers and a

clean cutter (puncher) away from contamination sources (cigarette smoke and organic solvent vapors – including solvent-based pens). See Chapter 6.3.3 in (EN 12341:2014, 2014) and Chapter 7. in (EN 16909:2017, 2017) for details.

Intercomparison Measurement Campaign and Analysis



Instruments preparation, calibration, and daily quality control

The three instruments (DRI 2015 – reference unit, DRI 2015 Upgrade kit, DRI 2015 Series 2) were prepared according to the Supplement section "Tests performed". During the intercomparison campaign, routine validations with bake and sucrose were performed at the beginning of measurements each day. Every week of the intercomparison campaign the stability of the transmittance laser signal was monitored with instrument blank analysis. The laser signals did not deviate more than 3% from their average values during the instrument blank analysis (EN 16909:2017, 2017). For instrument blank, the EUSAAR2 thermal protocol was chosen.

Data analysis

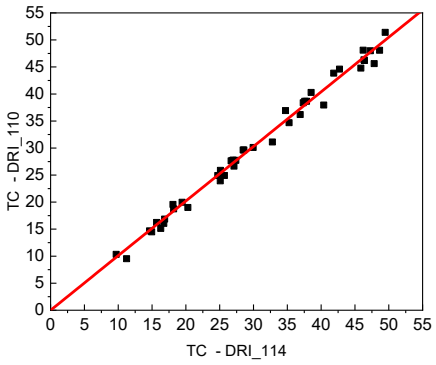
The analysis was performed according to (EN 16450:2017, 2017). Linear orthogonal regression results are shown with s as the slope for the model without an intercept; and with s_1 as the slope and i as the intercept for the model with an intercept (EN 16450:2017, 2017). R_{xy}^2 is the square of the Pearson correlation coefficient. A total of 22 samples were collected for the offline comparison, but analysis was done with two thermal protocols; IMPROVE_A and

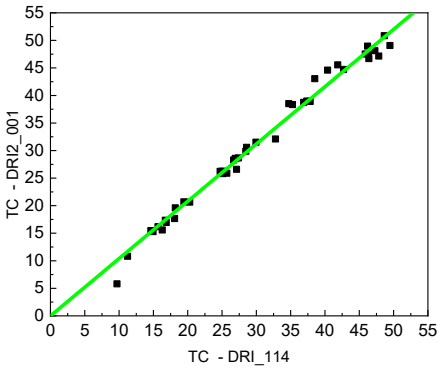
EUSAAR_2 (Chow et al., 2009; Cavalli et al., 2010). Therefore, 44 points are used in the analysis dataset.

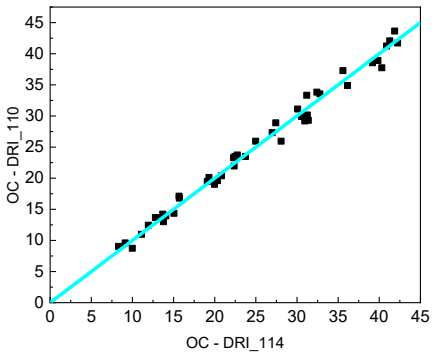
The table and graphs below show the results of orthogonal regression without intercept.

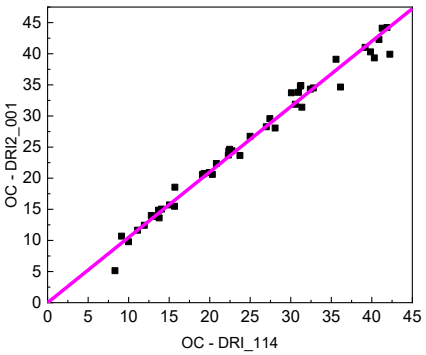
Orthogonal regression results
$y = s \cdot x$

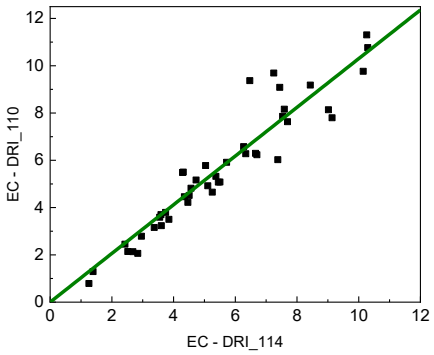
x	y	N	R_{xy}^2	s
TC_{DRI_114}	TC_{DRI_110}	44	0.99	1.01 ± 0.01
TC_{DRI_114}	TC_{DRI2_001}	44	0.99	1.04 ± 0.01
OC_{DRI_114}	OC_{DRI_110}	44	0.98	1.00 ± 0.01
OC_{DRI_114}	OC_{DRI2_001}	44	0.98	1.05 ± 0.02
EC_{DRI_114}	EC_{DRI_110}	44	0.90	1.03 ± 0.02
EC_{DRI_114}	EC_{DRI2_001}	44	0.95	1.01 ± 0.02

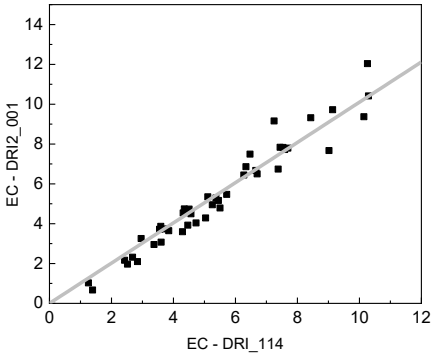









EC - DRI_110
EC - DRI_114
0
2
4
6
8
10
12


EC - DRI2_001
EC - DRI_114
0
2
4
6
8
10
12
14

Conclusions

The DRI2015 Series 2 and DRI2015 Upgrade Kit instruments passed the equivalence test for TC, OC, and EC measurements in comparison with the DRI2015 reference instrument, as the values of the slopes are $0.90 < s < 1.10$. The values for the TC, OC, and EC intercepts i is below 1.0 µg/cm2 for orthogonal regression with intercept (see Supplement - Intercomparison data analysis results - orthogonal regression with intercept for details).

Additionally, two DRI-2015 Series 2 instruments were successful in the ACTRIS inter-laboratory comparison project for TC and EC measurements (OCEC-2022-1) at the European Center for Aerosol Calibration (ECAC). In this project, 29 laboratories from 18 countries, with 31 analyzers in total, participated in February and March 2022.

ACTRIS is a large European Research Infrastructure consisting of 22 countries and more than 100 research organizations committed to research of short-lived atmospheric constituents.

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