Metrological challenges to tackle climate change (IMEKO TC8, TC11 and TC24 2023 Conference)

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The present special issue collects the extended version of some of the contributions presented at the IMEKO TC8-TC11-TC24 Joint Conference, held in Funchal (Portugal) in October 2023. Thanks to the participation of researchers and professionals from all over the world, the event has been an eminent forum covering different fields of metrology: measurement traceability, testing and inspection, and chemical metrology.

The published papers show the relevance of measurement science to support energy transition and to monitor the pollution levels in the atmosphere. Indeed, measurement traceability and newly developed certified reference materials allow the scientific community to properly address the new challenges posed by such topics.

The paper 'An inter-laboratory comparison between 13 international laboratories for eight components relevant for hydrogen fuel quality assessment' [1] addresses the important issue of impurities detection in hydrogen delivered to refuelling stations. Indeed, fuel-cell electric vehicles require extremely pure hydrogen, and the presence of trace-level contaminants (e.g., carbon monoxide, hydrogen sulphide, ammonia) may reduce the lifetime of the fuel-cell hardware, affecting the safety of end-users. To overcome this challenge, several European laboratories are developing the capability to measure the contaminants specified in ISO 14687:2019 and EN 17124:2022 standards, which are pertinent for refuelling stations. Thus, the purpose of the paper is to present a new and extensive inter-laboratory comparison (ILC) including eight contaminants. The study was performed during the project '19ENG04 MetroyVe2' and included nitrogen (N_2), carbon monoxide (CO), carbon dioxide (CO_2), propane (C_3H_8), oxygen (O_2), water (H_2O), tetrachlorohexafluorobutane ($C_4Cl_4F_6$) and hydrogen sulphide (H_2S) or carbonyl sulphide (COS)), all in one cylinder. These compounds were selected based on their high probability of occurrence or because they have been found in hydrogen fuel samples. The number of participants that signed up for this ILC was 13, nine in Europe, three in Asia and one in USA. The results of the ILC are presented, providing also insights related to future challenges in hydrogen purity assessment.

In the paper 'Preparation of multicomponent mixtures to support carbon metrology'[2], the Authors present the methodology to produce Certified Reference Materials (CRM) relevant to measure impurities in CO_2 with the associated uncertainties and metrological traceability. Indeed, it is important to highlight the relevance of certified gas mixtures in environmental monitoring and decarbonisation research, as they are essential for calibrating the instruments that measure atmospheric pollutants and greenhouse gases. In this study, the Authors prepared different gas mixtures containing CO_2 and other components that are common in the atmosphere. The subsequent chemical analysis reveals the possible cross-interference between

the different gases composing the prepared mixtures. Future work will address the stability of the gas mixtures, to establish their shelf life; moreover, new mixtures with more components will be prepared and studied.

The same metrological issue is addressed in the paper 'Stability study and uncertainty evaluation of CO_2 certified reference materials for greenhouse gases monitoring'[3]. In this manuscript, the Authors describe two independent metrological traceability paths established at INRiM (Istituto Nazionale di Ricerca Metrologica) for the preparation of gaseous certified reference materials (CRMs) at atmospheric CO_2 amount fraction. The aim of this publication is to show a method for evaluating the uncertainty associated with CRM stability and to demonstrate that there is no significant trend in the results over time. Such CRMs are produced as an intermediate step towards the development of novel generation CRMs certified also for the isotopic composition.

The last paper belonging to the special issue, titled 'Metrological traceability of moisture/water content measurements'[4], focuses on measurements to characterize plant-origin materials, which are necessary to support quality and fair trade in the cereals market. Indeed, the term "moisture", often used in this context, is generic and it does not identify a specific measurand. Consequently, to declare proper Calibration and Measurement Capabilities (CMCs) and to develop Certified Reference Materials (CRMs), a better specification of the measurand should be given. Currently, no CMCs for moisture or water content measurements in the plant-origin bulk materials, as well as respective CRMs, are available in the Key Comparison Database (KCDB) published on the website of the Bureau International del Poids et Mesures (BIPM). In the paper, commonly used methods for moisture and water content measurements in plant-origin materials are analysed. The main aim of the work is to highlight the advantages and drawbacks of the different methods and to select a suitable way for plant matrix CRMs for water content that would provide traceability to SI and support CMC claims. The Authors show that CRMs characterized for water content by Karl Fischer titration method are the most promising candidates for this application.

In conclusion, we would like to express our gratitude to all the Conference attendees, who contributed to creating an inspiring and lively event for knowledge dissemination in such important metrological fields.

[1] K. Arrhenius, A. Morris, M. Hookham, N. Moore, P. Modugno, T. Bacquart, An inter-laboratory comparison between 13 international laboratories for eight components relevant for hydrogen fuel quality assessment, Measurement, Volume 230, 2024, 114553, DOI: 10.1016/j.measurement.2024.114553 .

[2] F. A. Dias, C. Palma, C. J. Costa, Preparation of multicomponent mixtures to support carbon metrology, Measurement, Volume 239, 2025, 115453, DOI: 10.1016/j.measurement.2024.115453 .

[3] F. Durbiano, F.R. Pennecchi, F. Rolle, S. Pavarelli, M. Sega, Stability study and uncertainty evaluation of CO2 certified reference materials for greenhouse gases monitoring, Measurement, Volume 232, 2024, 114653, DOI: 10.1016/j.measurement.2024.114653 .

[4] S. Kulyk, O. Shcherbakova, F. Durbiano, F. Rolle, M. Sega, A. Petrenko, O. Melnykov, Metrological traceability of moisture/water content measurements, Measurement, Volume 242, Part A, 2025, 115845, DOI: 10.1016/j.measurement.2024.115845 .