Fifteen visiting scientists from NMIs participated in the Chemistry Department Programme in 2018. Six comparisons were run by the department in this period, involving eighty participations by NMIs in these studies. The Capacity Building and Knowledge Transfer (CBKT) programmes for “Metrology for Clean Air” and “Safe Food and Feed” continued, attracting seven of the fifteen visiting scientists from NMIs, who spent between three months and one year at the BIPM.

**Metrology for Clean Air**

Three visiting scientists from the NPLI (India), NMISA (South Africa) and KazInMetr (Kazakhstan) undertook the Metrology for Clean Air Course on FTIR Measurements on Gas Standards (NO$_2$, HCHO, HNO$_3$, CO$_2$) in the BIPM laboratories. They received training in the use of B-FOS software for use with Fourier Transform Infrared (FTIR) in gas metrology applications; the software was made available later for use within the participating NMIs. Short training courses on the use of B-FOS FTIR software were also provided to visiting scientists from NMIJ (Japan) and PTB (Germany).

**Metrology for Safe Food and Feed**

The third meeting for the CBKT programme on “Metrology for Safe Food and Feed”, focusing on mycotoxin metrology and standards, was held at the BIPM in April 2018. The laboratory programme on mycotoxin standards was supported by three visiting scientists from NIM (China) working on related structure impurity analysis, calibration solution characterization, and qNMR for aflatoxin B1 and deoxynivalenol materials, as well as a visiting scientist from UME (Turkey) characterizing pure patulin material. In addition, two visiting scientists from UME and NMISA undertook three-month training secondments on non-related structure impurity quantification in mycotoxin pure materials. Stock solutions of zearalanone have been provided to all NMIs that have participated in the programme to date (KEBS, INTI, NMISA, NIMT, INMETRO, UME). The first key comparison (CCQM-K154.a) on mycotoxin calibration solutions was launched in the last quarter of 2018. NMI-prepared calibration solutions underwent comparison measurements at the BIPM in December 2018, with ten NMIs participating. A paper summarizing the mycotoxin standard preparation and validation was published.[22]

**Launch of qNMR Internal Standard Reference Data**

The BIPM has published a set of reference data to support laboratories worldwide that use quantitative Nuclear Magnetic Resonance (qNMR) for the purity assignment of organic compounds, thereby aiding the development of primary reference materials for SI traceable calibration hierarchies in organic analysis as well as Reference Standards and assays for pharmaceutical laboratories. The “qNMR Internal Standard Reference Data” documents were developed as part of a BIPM-NMIJ (Japan) collaboration together with visiting scientists from NIM (China), INMETRO (Brazil) and UME (Turkey) at the BIPM.

The publications cover a set of seven “universal calibrators” for qNMR, identified by the NMIJ and the BIPM as being able to serve as an ensemble of internal standards that would enable purity assignment measurements by proton qNMR of the vast majority of organic analyte/solvent combinations.

The seven standards that make up the qNMR universal calibrator set are:
- maleic acid
- dimethyl sulfone
- potassium hydrogen phthalate
- 3,5-bistrifluoromethyl benzoic acid
- dimethyl terephthalate
- 1,4-bistrimethylsilylbenzene
- 3-trimethylsilyl propanesulfonic acid sodium salt-d6

The development and publication of the documents were presented by the BIPM during an invited lecture on the “Role and Use of Reference Materials to underpin SI-Traceable measurements for qNMR” at the qNMR Summit 2018 in Tokyo on 29–30 January 2018.

**Small organic primary calibrator programme**

The final report of the CCQM-K55.d comparison on folic acid purity was published and the final report for the CCQM-K78.a comparison on multi-component amino acid calibration solutions was completed and circulated to the CCQM for approval in November 2018. Samples for the CCQM-K148.a comparison (bisphenol A calibrator purity) were distributed, with 20 NMIs participating, and results were submitted to the BIPM in February 2019.
Peptide and protein primary standard comparisons
Support for the CCQM programme of peptide and protein primary standard comparisons continued. Preparative work for the comparison on oxytocin (CCQM-K155.b) was completed in collaboration with NIM (China) and with the secondment of a visiting scientist from NIM. Samples for the comparison have been distributed with results to be submitted to the BIPM by the end of December 2018. There are 12 participant NMIs in this comparison. Characterization work on pure hexapeptides of HbA1c for comparisons on the HbA1c glycated hexapeptide (GE), for CCQM-K115.c, and the non-glycated hexapeptide (VE), for CCQM-K115.2019, have continued with the support of a visiting scientist from NIMT (Thailand), and in collaboration with HSA (Singapore), LNE (France) and NIM. Methods developed for pure peptide characterization were published in Analytical and Bioanalytical Chemistry[23] and an invited review paper.[24]

Greenhouse gas standards
In the area of greenhouse gas standards, the final report of the CO₂ in air standards comparison CCQM-K120 has been published. The comparison demonstrated a reduction in the reference value uncertainty by a factor of four compared to comparisons performed previously. In addition, it demonstrated the improvements in the accuracy of standards and comparison methods that can now be achieved. The BIPM’s CO₂ PVT primary system, which is based on manometry, was compared in the pilot study CCQM-P188, which was performed in parallel to the key comparison. Good agreement was observed with this method at levels of uncertainty equivalent to those that can be achieved using gravimetric methods. The development and validation of a manometric system for CO₂ measurements, in support of a future planned ongoing comparison of CO₂ standards (BIPM.QM-K2), has progressed with a second secondment from the NIST. Development work will continue, with characterization of adsorption and trace gas effects as well as automation of the system planned. Preparation for a comparison on CO₂ isotope ratio standards, coordinated jointly by the BIPM and the International Atomic Energy Agency (IAEA) continued, with an isotope ratio infrared spectrometer (IRIS) system for isotope ratio measurements integrated into the SIRM-GEN facility. The first blending experiments for CO₂ gases have been carried out with support from visiting scientists from INRIM (Italy) and VNIIM (Russia). Samples prepared at the BIPM were sent and measured at the IAEA. The NMIJ has donated highly-characterized pure CO₂ gas to the BIPM to support the validation work that is being carried out. A review paper summarizing standards activities for greenhouse and air quality gases has been published.[26] In addition, a review of SI traceable versus scale approaches for metrological traceability for greenhouse gas monitoring has been published.[27]

Air quality measurement standards
In the area of air quality measurement standards, the BIPM continued to contribute to the CCQM Working Group on Gas Analysis (CCQM-GAWG) Ozone Cross Section Task Group. A paper summarizing the recommended best value and uncertainty for the ozone cross-section to be used in the key comparison BIPM.QM-K1 was submitted to Metrologia. Three NMIs: FMI (Finland), NILU (Norway) and NPLI (India) sent their ozone standards to the BIPM and participated in BIPM.QM-K1, with a report[25] of the comparison being published. One calibration of an ozone standard was performed for NILU. Collaboration with the NIST (USA) on the upgrade of the electronic module for the Ozone Standard Reference Photometer (SRP) continued. The 2018 version of the prototype electronics module was successfully constructed and tested at the BIPM; the operating software is being developed by NIST. The Draft A report of CCQM-K137 (NO in N₂ at 30 μmol/mol and 70 μmol/mol) was completed and the key comparison reference value (KCRV) was agreed by the CCQM-GAWG in October 2018. Measurements at the BIPM for the comparison of NO₂ in N₂ standards at 10 μmol/mol (CCQM-K74.2018) and the pilot study of HNO₃ measurements in such standards (CCQM-P172) have started with 33 participating NMIs.