

Report on the BIPM Workshop on “Physiological Quantities and SI Units”

A Workshop on “Physiological Quantities and SI Units” was held at the BIPM on 16 and 17 November 2009.

Rationale for organizing the Workshop

Physiology is the study of the mechanical, physical and biochemical functions of living organisms. In recent years needs have increased to quantify the effects of a multitude of factors on the human body in particular relating to health and safety issues. To quantify these effects in an objective and comparable manner it is necessary to first properly define suitable measurands and then provide, to the largest possible extent, their traceability to appropriate SI units. Guidance on the evaluation of measurement uncertainty also needs to be developed in some cases, for instance where physiological measurands are referred to diverse measurement scales such as the ordinal or where measurements are qualitative and/or multivariate.

Section 1.6 of the latest edition of the “SI Brochure” (2006) states that “Units for quantities that describe biological effects are often difficult to relate to units of the SI because they typically involve weighting factors that may not be precisely known or defined, and which may be both energy and frequency dependent.”

These challenges are not only recognized by the metrologists involved, but also by the international standardization bodies and other international organizations active in the field. The BIPM therefore organized a Workshop on the topic “Physiological Quantities and SI Units”, with the help of a Scientific Steering Committee composed of experts. Michael Kühne, BIPM, acted as the Chairman of the Workshop, and Claudine Thomas, BIPM, as the Scientific Secretary.

The aim of the Workshop basically was to bring together various interested communities, principally those concerned with traceable, reliable and comparable measurement, and those responsible for writing and applying specification standards and/or health and safety legislation, in order to spot potential challenges and to identify what the steps forwards could be.

Programme of the Workshop

The programme is available on the [Workshop page](#) of the BIPM website, and reproduced in the Annex to this document.

The workshop was limited to the topic of “Health and Safety for Humans” with presentations by twelve metrology experts covering the six fields selected by the Scientific Steering Committee:

- Optical Radiation (infrared, visible light, ultraviolet),
- Radio Waves and Microwaves,
- Ionizing Radiation,
- Sound and Ultrasound,
- Magnetic Fields, and
- Biological quantities.

In addition short presentations were given on the new ISO/IEC series 80003, the WHO international standards and units, and on the European "MINET" project dealing with measurement dependent on human perception and/or interpretation involving all five senses.

For each of the fields covered by presentations, time was spared for discussion using a skeleton of questions aimed at drawing up the state-of-the-art in the domain, further challenges, and the adequacy of the relationship between the world of metrology institutes and the world of standardization and regulation.

Attendance

The Workshop gathered some 70 people from about 22 countries all over the world. Most of them are working in National Metrology Institutes (NMIs), and are also active in Technical Committees or Working Groups of International Committees, Institutions or Unions such as ISO, IEC, CIE, ICRU, IUPAC, IUPAP, etc (summarized in this report under the acronym "IGOs").

General observations by the Workshop participants

1. There was a unanimous feeling of satisfaction with the presentations themselves, the answers the speakers and other experts provided to questions, and the field-specific as well as the general discussions. It appeared that progress is on-going in all of the areas approached at the Workshop.
2. The subject of "Physiological Quantities and SI Units" encompasses many different subjects in Physics, Chemistry and Biology that are or could be addressed inside NMIs and Institutes, and which may need written standards, vocabularies, documentation etc. that are or could be addressed inside dedicated IGOs such as ISO, CIE, etc. **The link between both should probably be done directly wherever possible between the relevant Consultative Committee (CC) of the CIPM or the relevant Joint Committee (for instance the JCTLM) and the relevant Technical Committee of the IGO (often being a member of the CC), field by field.**
3. At the time of the first meeting of the Scientific Steering Committee, the idea emerged to create a Working Group, which could be established as a joint group reporting to the JCGM and the CCU. After the Workshop, it became clear that such a new horizontal structure would mostly duplicate existing efforts and would not bring significant help in view of the diversity of subjects.
4. There is a strong feeling that **the individual CC Working Groups in charge of Strategic Planning should take on-board any new challenge related to physiological quantities in their domain of activities, and propose to their CC appropriate steps forward.** This mainly applies for the CCAUV, the CCPR, the CCEM and the CCRI. Invitation of additional IGOs to participate in CCs work could further evolve into new memberships.
5. The next edition of the SI Brochure should include more information on physiological quantities and SI units, through additional chapters or appendices or through an extension of the present Appendix 3. To accomplish this, the CCU will need inputs from the relevant CCs.
6. Presentations of the Workshop show that physiological quantities follow a general pattern, in which the challenge lies in developing an appropriate "action spectrum" [or "weighting function", "weighting factor", "model", etc.]. When this is established, the resulting quantity is generally expressed in SI units.
 - Each community designs its action spectra and models: this involves the relevant metrology community, often at the level of the appropriate CC, and international bodies which carry on standardization activities in the field (for example: collaborative development by the CCPR and the CIE of a new

- model involving a global parametric weighting function for scotopic, mesopic and photopic vision).
- The uncertainty is generally not well established.
 - Biological relevance and suitability are not always satisfactory.
 - Psychophysical, mental and behavioural processes are known to affect significantly the human response to various stimuli, making an action spectrum highly variable in some cases.
 - There are limitations in the application of the models, for instance to low level effects or in case of saturation effects, and there is certainly a case for model development, especially computer models.
 - It could be worthwhile to establish a connection with the JCGM WG 1 as concerns modelling of “action spectra” and eventually to include appropriate guidance on this topic into the planned GUM supplement on modelling.
7. The potential for harmonization of terms was emphasised. Experts are also welcome to comment on the drafts for the six parts of ISO/IEC 80003, *Quantities and units used in physiology*, which will be circulated in 2010 [Such comments should preferably be sent through their National member bodies of ISO or IEC]. The JCGM WG 2 may have to consider the concept of “physiological quantity”, which is not defined in the VIM 3rd Edition. The idea of splitting the SI into two classes, one for quantities in pure physics and another for quantities in physiology, was expressed, but not supported especially by the Optical Radiation community, at least for the time being.
 8. Cooperation between different partners, with cross-representation in each field, is highly encouraged. The established collaborations CCPR/CIE, CCQM/JCTLM/WHO [specifically on the WHO International Standards and International Units], and CCR/ICRU provide good examples. It is clear, however, that cooperation with and among biologists, radio-biologists, medical physicists (IFOM, EOMP), regulators and users is not yet always effective. Additional workshops and forums may be useful to increase awareness at the national, regional and international levels.
 9. Though formal regulation and legislation exist in most of the fields, they may not be uniform throughout the world. Regulators should inform NMIs and IGOs on how best they could be involved. In an increasing number of regulatory fields, traditional physiologically-based regulations are now adding human factors such as cognitive ability, reflecting the fact that human responses need also to account for psychophysical, mental and behavioural processes.
 10. Two cases where straight actions could be taken arose during the Workshop:
 - Contact should be established between the CCEM and the ICNIRP, the International Committee for Non-Ionizing Radiation Protection [The ICNIRP provides advice in this matter which is often taken onboard by regulatory bodies]. Effects induced by magnetic fields on the human body have not been considered in the framework of the CCEM: an appropriate action from the CCEM WG on Strategic Planning may be required;
 - It would be desirable that the Working Groups on Strategic Planning of the CCEM and of the CCPR consider the case of Radiation at frequencies at order Terahertz. This field may helpfully be tackled with through the creation of a joint group of the CCEM and the CCPR.

Acknowledgments

Michael Kühne and Claudine Thomas are grateful to the membership of the Scientific Steering Committee (Bruno Chauvenet, LNE-LNHB, Pedro Espina, BIPM, Teresa Goodman, NPL, Yoshi Ohno, NIST, Jenny Pellaux, ISO, Leslie Pendrill, SP, Malcolm Sperrin, Royal Berkshire Hospital, UK, Emma Woolliams, NPL, Bajram Zeqiri, NPL) and additional experts (Jörn Stenger, PTB, CCU, IUPAP/SUNAMCO; Walter Bich, INRIM and JCGM WG 1; Alan Steele, NRC) for their involvement in the smoothed operation of the Workshop and for their help in drawing up conclusions.

Annex: Agenda/Programme of the Workshop

16 November 2009

- 09:00 – 09:10 Welcome
Prof. Andrew Wallard, Director, BIPM
- 09:10 – 09:30 Statements of the objectives
Prof. Michael Kühne, Deputy Director, BIPM

Session 1

Chair: Prof. Michael Kühne, BIPM

Co-Chair: Ms Teresa Goodman, NPL

- 09:30 – 10:30 **Optical radiation (ultraviolet, visible light, infrared)**
- Introduction: Dr Yoshi Ohno, NIST
 - Photobiological quantities, Dr Ann Webb, University of Manchester
 - Perceptual responses to optical radiation, Ms Teresa Goodman, NPL
 - Physiology-based colorimetry, Prof. Françoise Viénot, MNHN
- 10:30 – 11:00 Discussion on issues related to optical radiation
- 11:00 – 11:30 *Coffee break*
- 11:30 – 12:15 **Radio waves and microwaves**
Dr Benjamin Loader, NPL
- Experimental dosimetry for mobile telecommunications and health (the UK MTHR programme)
 - SAR standards for traceable measurement of the specific absorption rate of energy
 - Legislation issues regarding electromagnetic fields (EMF) exposure
- 12:15 – 13:00 Discussion on issues related to radio- and micro- waves
- Information on the new ISO/IEC series 80003, Prof. Anders Thor and Dr Paul Gérôme, ISO
- 13:00 – 14:00 *Lunch*

Session 2

Chair: Prof. Michael Kühne, BIPM,

Co-Chair: Prof. Malcolm Sperrin, Royal Berkshire Hospital, UK

- 14:00 – 14:45 **Ionizing radiation**
Dr Penelope Allisy-Roberts, BIPM
- Radiation protection
 - New quantities
 - Nano-dosimetry
- 14:45 – 15:30 Discussion on issues related to ionizing radiation
- Information on the European joint research projects “External beam cancer therapy” and “Increasing cancer treatment efficacy using 3D brachytherapy”, Dr Hans-Michael Kramer, PTB
- 15:30 – 16:00 *Tea break*

- 16:00 – 16:45 **Sound and ultrasound**
Prof. Victor Humphrey, ISVR
- The nature of sound
 - The ear and audiology
 - Physical effects of sound and ultrasound
 - Airborne sound
 - Airborne ultrasound and infrasound
 - Ultrasound in the body
 - Therapy fields

16:45 – 17:30 Discussion on issues related to sound

17:30 – 18:00 Conclusions of the day

17 November 2009

Session 3

Chair: Prof. Michael Kühne, BIPM,

Co-Chair: Prof. Leslie Pendrill, SP

- 09:00 – 09:45 **Magnetic fields (AC, DC, intense magnetic fields)**
Dr Bernd Ittermann, PTB
- Regulatory issues
 - Physiological effects of static magnetic fields
 - Slowly varying magnetic fields and motion in gradient fields

09:45 – 10:30 Discussion on issues related to magnetic fields

- 10:30 – 11:00 **WHO International Standards and International Units**
Dr René Dybkaer, REGION H Frederiksberg Hospital
- Definitions
 - Types of quantities and units
 - Regulatory requirements
 - Production of WHO International Standards
 - Assignment of a value
 - Metrological traceability
 - Uncertainty budget
 - Commutability
 - Needed development

11:00 – 11:30 *Coffee break*

- 11:30 – 12:15 Discussion on issues related to physiological quantities not expressed using SI units
- WHO standards and units
 - Information on the European “Measuring the Impossible” Network MINET, Prof. Leslie Pendrill, SP
 - Description - measurement dependent on human perception and/or interpretation
 - Present main achievements of the MINET consortium
 - Application of metrological issues to the “Measurement of Persons”

12:15 – 13:00 Conclusions of the Workshop