OPCW

Scientific Advisory Board

Twenty-Fifth Session
27 – 31 March 2017

SAB-25/1*
31 March 2017
Original: ENGLISH

REPORT OF THE SCIENTIFIC ADVISORY BOARD AT ITS TWENTY-FIFTH SESSION

1. AGENDA ITEM ONE – Opening of the session

The Scientific Advisory Board (SAB) met for its Twenty-Fifth Session from 27 to 31 March 2017 at the OPCW Headquarters in The Hague, the Netherlands. The session was chaired by Dr Christopher Timperley, with Mr Cheng Tang as Vice-Chairperson, both of whom were re-elected by the members of the Board.

2. AGENDA ITEM TWO – Adoption of the agenda

The SAB adopted the following agenda for its Twenty-Fifth Session:

1. Opening of the session
2. Adoption of the agenda
3. *Tour de table* to introduce Scientific Advisory Board members
4. Establishment of a drafting committee
5. Welcome address by the Director-General
6. Overview of developments at the OPCW since the last session of the Scientific Advisory Board
   - (a) General updates
   - (b) Removal and destruction operations
   - (c) Updates from the Open-Ended Working Group on Future Priorities
7. Engagement with the scientific community

   International Union of Pure and Applied Chemistry
8. Developments in science and technology
   - (a) Nanotechnology
   - (b) Monitoring activities of the Technical Secretariat

* Reissued in English for technical reasons.

CS-2017-0317(E) distributed 25/04/2017

9. Scientific and technological elements of verification technologies, emerging technologies, and new equipment

   (a) OPCW Fact-Finding Mission

   (b) Toxins

   (c) Comprehensive Nuclear-Test-Ban-Treaty Organization International Monitoring System

   (d) *Underworlds*

   (e) Inspectorate training

   (f) Computational chemistry and the Chemical Weapons Convention: Insights into the reactivity of Levinstein mustard by density functional theory

10. Medical countermeasures, treatment, and response to chemical agents

    Challenging chronic effects of sulfur mustard exposure through gene therapy

11. Advice on chemicals

    Updates to the Scientific Advisory Board's previous advice on riot control agents

12. Advice on chemical forensics and investigative technologies

    (a) Chemometrics in evidence evaluation

    (b) Update on the formation of a temporary working group on investigative science and technology

    (c) Chemical forensics and evidence management: standard operating guidelines

13. Future work of the Scientific Advisory Board

    (a) Road map of the Scientific Advisory Board's work

    (b) Twenty-Sixth and Twenty-Seventh Sessions of the Scientific Advisory Board

    (c) 2017 Scientific Advisory Board workshops

    (d) Preparation of the Scientific Advisory Board's recommendations to the Fourth Review Conference[1]

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[1] Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention.

(e) Horizon scanning and identification of key issues in science and technology: What can we learn from a Delphi study?

14. Any other business

15. Adoption of the report

16. Closure of the session

3. AGENDA ITEM THREE – *Tour de table* to introduce Scientific Advisory Board members

A *tour de table* was undertaken to introduce the SAB members. Four new members, Dr Pål Aas (Norway), Dr Renate Becker-Arnold (Germany), Dr Evandro De Souza Nogueira (Brazil), and Professor Ahmed Saeed (Sudan) attended their first session of the SAB. A list of participants in the Twenty-Fifth Session of the SAB appears in Annex 1 to this report.

4. AGENDA ITEM FOUR – Establishment of a drafting committee

The SAB established a drafting committee to prepare the draft report of its Twenty-Fifth Session.

5. AGENDA ITEM FIVE – Welcome address by the Director-General

5.1 The Director-General of the OPCW Technical Secretariat (hereinafter "the Secretariat") delivered a welcome address thanking the Chairperson, Vice-Chairperson, and members of the Board for the significant contributions they had made and welcoming those whose membership on the Board was just beginning. He expressed appreciation for the science-policymaker discourse that the Board had championed, noting that the strengthening of scientific literacy among the OPCW delegations ensured that scientific and technical dimensions of Convention implementation received due consideration.

5.2 Calling attention to the upcoming celebrations of the OPCW's twentieth anniversary,[2] the Director-General pointed to the important role the SAB had played across the OPCW's history, and called on the Board to continue with a forward-looking view towards shaping the future. He emphasised, just as recent events had shown, that future challenges to the Chemical Weapons Convention (hereinafter "the Convention") would differ from those of the past. Reflecting on the challenges ahead, the Director-General called on the SAB to recognise scientific change that may offer opportunities, realisable through the translation of science into viable policy options. In this context, he thanked the Vice-Chairperson for his briefing to the Open-Ended Working Group on the Future Priorities of the OPCW (OEWG-FP) about the SAB's views of the future of verification (see also paragraph 6.5 below). The Director-General noted that while States Parties may not embrace all of the advice coming from the Board, the challenges to assumptions and discussion provoked by this scientific advice served to keep policymakers better informed in their decision making. The Director-General called attention to the SAB's upcoming

[2] OPCW at 20. See: https://20years.opcw.org/

report to the Fourth Review Conference on scientific developments, noting that this document provided further opportunity to consider technical needs and challenges as inputs to help shape the future.

5.3 Addressing the need to develop and maintain capabilities necessary for the OPCW to remain fit for purpose in preventing the re-emergence of chemical weapons, the Director-General looked to the SAB to review the terms of reference for a temporary working group (TWG) on investigative science and technology, and to begin the process of setting up such a group, noting that the outcomes of this TWG would enhance the capabilities of the Organisation. The Director-General further noted the value of engaging with members of the Secretariat to understand their needs as the SAB developed recommendations.

5.4 The welcome address concluded with an acknowledgement of the SAB members whose terms on the Board would end before the next session, praising them for their contributions and dedication to seeing a global commitment to the norms of the Convention.

6. AGENDA ITEM SIX – Overview of developments at the OPCW since the last session of the Scientific Advisory Board

Subitem 6(a): General updates

6.1 The Secretariat's Science Policy Adviser and Secretary to the SAB, Dr Jonathan Forman, briefed the Board on developments at the OPCW since the SAB's Twenty-Fourth Session. He began with information on the OPCW's twentieth anniversary, provided updates on destruction and non-proliferation activities, touched on developments across science and technology relevant to units of the Secretariat, and highlighted recent working group and advisory body activities. Turning to SAB recommendations, Dr Forman reviewed key points from the Director-General's response to the report of the Twenty-Fourth Session of the SAB (EC-84/DG.9, dated 18 January 2017),[3] and noted the ongoing work on which the Secretariat would brief the Board later in 2017. Dr Forman also provided updates on the Board's science-policymaker engagement activities, including a side event on science advice to the Eighth Review Conference of the Biological and Toxins Weapons Convention,[4]

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3 Available at: www.opcw.org/fileadmin/OPCW/EC/84/en/ec84dg09_e_.pdf

4 (a) Science advice at the OPCW (presented by Dr Jonathan Forman): http://www.unog.ch/80256EDD006B8954/(httpAssets)/CAB209422758487FC12580830049685 3/$file/OPCW1_Science_Advice_Policy-Maker_Engagement_in_CWC.pdf
(b) The OPCW Scientific Advisory Board (presented by Dr Christopher Timperley): http://www.unog.ch/80256EDD006B8954/(httpAssets)/C58378ED81AB8EC8C125808300495BAC/$file/opcw2_scientific_advisory_board.pdf
(c) The Role of Designated Laboratories (presented by Professor Paula Vanninen): http://www.unog.ch/80256EDD006B8954/(httpAssets)/D15A6BEA6AB55D5BC125808300494E83/$file/opcw3_role_of_designated_labs.pdf
(d) Advice on Chemical Warfare Agent Toxicity and Emergency Response (presented by Dr Zrinka Kovarik): http://www.unog.ch/80256EDD006B8954/(httpAssets)/4D4AB75268B182A8C125808300493D7E/$file/opcw4_medical_countermeasures.pdf
(e) The Hague Ethical Guidelines (presented by Mr Cheng Tang): http://www.unog.ch/80256EDD006B8954/(httpAssets)/AD7219F302D47A12C12580830048E430/$file/OPCW5_The+Hague+Ethical+Guidelines.pdf

the SAB Chairperson's Briefing to the Twenty-First Session of the Conference of the States Parties,[5] and recent briefings from the Science for Diplomats initiative.[6]

6.2 Speaking about opportunities to engage with scientific communities, Dr Forman updated the SAB on several of the Secretariat's new international cooperation initiatives that were continuing in 2017. These included the symposium on women in chemistry in May,[7] the policy and diplomacy for scientists workshop in September,[8] and the green chemistry expert group meeting in November. He continued with a discussion on notable scientific conferences at which the OPCW and SAB members would be making contributions in 2017, including the 253rd American Chemical Society National Meeting & Exposition in April;[9] the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) Science and Technology Conference in June;[10] the 17th Asian Chemical Congress;[11] the 46th World Chemistry Congress of the International Union of Pure and Applied Chemistry (IUPAC) in July;[12] and the German Chemical Society's 150th anniversary event in September. Dr Forman announced that most of the spring 2016 ConfChem[13] papers had been revised, peer-reviewed, and published in IUPAC's flagship chemistry journal *Pure and Applied Chemistry*,[14] further raising the visibility of the OPCW in scientific communities.

Subitem 6(b): Removal and destruction operations

6.3 Mr Laurent Robert, Head of the OPCW Chemical Demilitarisation Branch, briefed the SAB on destruction activities related to Libya and Iraq. He first provided an overview of the removal operations of Category 2 chemical weapons from Libya and their current status, as reported to the Executive Council (hereinafter "the Council") at its Eighty-Fourth Session (EC-84/DG.23, dated 24 February 2017). He then updated the Board on the recent decision taken by the Council for the destruction of the chemical weapon remnants in Al Muthana (Bunker 13) in Iraq (EC-84/DEC.2, dated 8 March 2017).

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5 Statement available at: www.opcw.org/fileadmin/OPCW/SAB/en/SAB_Chair_Briefing_to_CSP21-statement.pdf. Slides to accompany the statement are available at: www.opcw.org/fileadmin/OPCW/SAB/en/SAB_Chair_Briefing_to_CSP21-slides.pdf

6 For more information see: www.opcw.org/special-sections/science-technology/science-for-diplomats/

7 For more information see: www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1458-2017_e_.pdf

8 For more information see: www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1466-2017_e_.pdf

9 For more information see: https://www.acs.org/content/acs/en/meetings/spring-2017.html

10 For more information see: https://www.ctbto.org/specials/snt2017/

11 For more information see: http://www.racicongress.com/17ACC/

12 For more information see: http://www.iupac2017.org/

13 2016 Spring ConfChem: Science, Disarmament, and Diplomacy in Chemical Education: The Example of the Organisation for the Prohibition of Chemical Weapons. http://confchem.ccce.divched.org/2016SpringConfChem

14 Science, disarmament and diplomacy in chemical education: the example of the Organisation for the Prohibition of Chemical Weapons – The Spring 2016 Confchem; R. E. Belford, J. E. Forman; *Pure and Applied Chemistry*; 2016, *1115*, ISSN (Online) 1365-3075, ISSN (Print) 0033-4545, DOI: https://doi.org/10.1515/pac-2016-1115 , January 2017.

Subitem 6(c): Updates from the Open-Ended Working Group on Future Priorities

6.4 Dr Alexander Kelle from the Office of Strategy and Policy briefed the Board on the establishment and work conducted by the OEWG-FP. He noted the forward-looking documents produced by the Secretariat and explained the establishment of the OEWG-FP in this context.[15] Dr Kelle identified the baseline documents that had been used by the OEWG-FP in the early stages of its work,[16] briefly mentioned the tentative programme of work the Group had given itself, and highlighted the topics and issue areas most noted by States Parties during the Group's November 2016 session on the OPCW's future relevance.

6.5 Concerning the OEWG-FP's work on the subject of verification, Dr Kelle noted how the work had been subdivided into separate presentation and discussion meetings. During the discussion meetings, States Parties received inputs both from the Secretariat and invited experts, including the SAB Vice-Chairperson, Mr Cheng Tang. Some of the recommendations of the SAB's TWG on verification[17] that Mr Tang referred to in his presentation had been receiving attention from several States Parties. In conclusion, Dr Kelle noted that in the oral report to the Council at its Eighty-Fourth Session, one of the Co-Chairpersons of the OEWG-FP had highlighted the fact that only 12 States Parties from three regional groups had intervened at the Group's most recent session.

6.6 In the subsequent discussion, the Board appreciated the updates from Dr Kelle and indicated that it stood ready to provide further views on the scientific dimensions of the OPCW's future work.

7. AGENDA ITEM SEVEN – Engagement with the scientific community

International Union of Pure and Applied Chemistry

7.1 Dr Mark Cesa, 2016-2017 Past President of IUPAC, provided the Board with an overview of IUPAC[18] and its work. IUPAC is the global organisation that provides objective scientific expertise and develops essential tools for the application and communication of chemical knowledge for the benefit of humankind and the world. IUPAC fosters sustainable development, provides a common language for chemistry, and advocates the free exchange of scientific information. Through its members,

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15 (a) Note by the Secretariat: "The OPCW in 2025: Ensuring a World Free of Chemical Weapons" (S/1252/2015, dated 6 March 2015). Available at: www.opcw.org/fileadmin/OPCW/S_series/2015/en/s-1252-2015_e_.pdf
(b) "Medium-Term Plan of the Organisation for the Prohibition of Chemical Weapons, 2017 – 2021" (EC-83/S/1 C-21/S/1, dated 8 April 2016). Available at: www.opcw.org/fileadmin/OPCW/EC/83/en/ec83s01_c21s01_e_.pdf

16 "Establishment of an Open-Ended Working Group on the Future Priorities of the OPCW" (EC-82/DEC.2, dated 14 July 2016).
Available at: www.opcw.org/fileadmin/OPCW/EC/82/en/ec82dec02_e_.pdf

17 Verification, Report of the Scientific Advisory Board's Temporary Working Group (SAB/REP/1/15, dated June 2015). Available at: www.opcw.org/fileadmin/OPCW/SAB/en/Final_Report_of_SAB_TWG_on_Verification_-_as_presented_to_SAB.pdf
See also: www.opcw.org/fileadmin/OPCW/SAB/en/VER_Poster_5102015.pdf

18 More information about IUPAC can be found on its website at: https://iupac.org/

volunteers, projects, publications, and conferences, IUPAC focuses on aspects of chemistry where global consensus is essential.

7.2 Noting that IUPAC and the OPCW had recently signed a memorandum of understanding to enhance cooperation between the two organisations,[19] Dr Cesa pointed out areas where the two organisations had collaborated for many years towards common goals. Examples included workshops that provide scientific input for the Conferences to Review the Operation of the Chemical Weapons Convention,[20,21,22] including the SAB's upcoming 2017 workshop on emerging technologies; the development and endorsement of The Hague Ethical Guidelines;[23,24] and tools and resources for education and outreach regarding the multiple uses of chemicals.[25] IUPAC serves as a resource of chemistry expertise, with several of its technical divisions, including the Analytical Chemistry Division, the Division on Chemistry and the Environment, the Division of Chemistry and Human Health, and the Committee on Chemistry and Industry, having volunteer experts who carry out projects and programmes of relevance to goals of the SAB. This is particularly true with respect to monitoring, detection, and quantification of chemicals in the environment.

7.3 In the subsequent discussion, the following points were raised:

(a) The SAB expressed its appreciation to Dr Cesa for his presentation and to IUPAC for its support and promotion of the norms of the Convention throughout its history.

(b) It was suggested that experts from IUPAC could provide advice on finding less toxic chemicals to replace certain widely used toxic industrial chemicals.

(c) The SAB recognised IUPAC's promotion of The Hague Ethical Guidelines as a productive way to promote the norms of the Convention within scientific communities. These guidelines serve as discussion points to inform codes of ethics/conduct and facilitate discussions on professional responsibility.

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19 See: https://www.opcw.org/news/article/opcw-and-international-union-of-pure-and-applied-chemistry-take-partnership-to-new-level/

20 For the First Review Conference: IUPAC workshop on the impact of scientific developments on the Chemical Weapons Convention, Bergen, Norway, 30 June –3 July 2002. The workshop proceedings were published in a special edition of *Pure Appl. Chem.*; 2002, *74 (12)*, 2229–2352. Available at: https://www.iupac.org/publications/pac/74/12/index.html

21 For the Second Review Conference: Impact of scientific developments on the Chemical Weapons Convention; M. Balali-Mood, P. S. Steyn, L. K. Sydnes, R. Trapp; *Pure Appl. Chem.*; 2008, *80 (1)*, 175–200. Available at: http://media.iupac.org/publications/pac/2008/pdf/8001x0175.pdf

22 For the Third Review Conference: Impact of scientific developments on the Chemical Weapons Convention; K. Smallwood, R. Trapp, R. Mathews, B. Schmidt, L. K. Sydnes; *Pure Appl. Chem.*; 2008, *85 (4)*, 851–881. Available at: https://www.iupac.org/publications/pac/pdf/2013/pdf/8504x0851.pdf

23 To find out more about The Hague Ethical Guidelines, see: https://www.opcw.org/special-sections/science-technology/the-hague-ethical-guidelines/

24 See https://www.opcw.org/news/article/iupac-endorses-the-hague-ethical-guidelines/

25 Multiple Uses of Chemicals. See http://multiple.kcvs.ca/site/index.html

8. AGENDA ITEM EIGHT – Developments in science and technology

Subitem 8(a): Nanotechnology

8.1 Mr Francois van Straten presented examples of recently published applications of nanotechnology applied to analysis,[26] detection,[27] protection,[28] decontamination[29] and medical countermeasures[30] relevant to chemical warfare agents. His overview provided insight into the status of development, as opposed to what was imagined to be possible. To put nanotechnology into a global perspective of recent trends, he described publications and patents[31] and global value.[32] Mr van Straten concluded his presentation with a review of published papers related to nanotechnology in regard to the Convention.[33,34,35]

8.2 Although nanotechnology had been applied to developing beneficial products for defence against chemical agents,[36] few novel commercial products were currently available in this field. Economically, nanotechnology was shown to be a growth area and, in the view of the presenter, any uses of nanotechnology for purposes prohibited by the Convention would be addressed under paragraphs 1 and 2 of Article II.[37]

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26 Analysis of chemical warfare agents in organic liquid samples with magnetic dispersive solid phase extraction and gas chromatography/mass spectrometry for verification of the Chemical Weapons Convention; V. Singh, A. Kumar Purohit, S. Chinthakindi, G. D. Raghavender D., V. Taka, D. Pardasani, A. R. Shrivastava, D. K. Dubey; *J Chromatogr A.;* 2016, *27*, 1448:32-41. DOI: 10.1016/j.chroma.2016.04.058.

27 Ultratrace detection of toxic chemicals: triggered disassembly of supramolecular nanotube wrappers; S. Ishihara, J. M. Azzarelli, M. Krikorian, T. M. Swager; *J. Am. Chem. Soc.*; 2016, *138 (26)*, 8221–8227. DOI: 10.1021/jacs.6b03869.

28 Ultra-fast degradation of chemical warfare agents using MOF–nanofiber kebabs; J. Zhao, D. T. Lee, R. W. Yaga, M. G. Hall, H. F. Barton, I. R. Woodward, C. J. Oldham, H. J. Walls, G. W. Peterson, G. N. Parsons; *Angew. Chem. Int. Ed.*; 2016, *55*, 13224–13228. DOI: 10.1002/anie.201606656.

29 Decontamination of chemical warfare sulfur mustard agent simulant by ZnO nanoparticles; M. Sadeghi, S. Yekta, H. Ghaedi; *Int. Nano. Lett.;* 2016, *6*, 161-171. DOI: 10.1007/s40089-016-0183-x.

30 Medical technology: using nanoparticles to treat phosgene exposure; S. Barua, G. Nichols; *HDIAC Journal*; 2016, *3*, 30-31. (https://www.hdiac.org/node/4339)

31 A Statistical Report on Nanotechnology Research Publications, 2017. (http://statnano.com /news/57667)

32 Will the science of atom-size objects reshape the economy?; P. Marshall; *CQ Researcher;* 2016, *26*, 505-528. (http://library.cqpress.com/cqresearcher/document.php?id=cqresrre2016061020)

33 (a) Is nanotechnology prohibited by the Biological and Chemical Weapons Conventions; R. D. Pinson, *Berkeley J. Intl. Law*; 2004, *22*, 279-309. (http://scholarship.law.berkeley.edu/bjil/vol22/iss2/4)
(b) A tiny problem with huge implications - nanotech agents as enablers or substitutes for banned chemical weapons: is a new treaty needed?; E. J. Wallach; *Fordham International Law Journal*; 2009, *33(3)*, 858-956. (http://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?article=2198&context=ilj)

34 Nanotechnology and the future of the law of weaponry; N. Hitoshi; *US Naval War College International Law Studies;* 2015, *91(2)*, 486-516; ANU College of Law Research Paper No. 15-27. (https://ssrn.com/abstract=2700385)

35 Chemical and Biological Weapons; R. J. Mathews in *Routledge Handbook of the Law of Armed Conflict*; R. Liivoja, T. McCormack (eds), 2016, Routledge; University of Melbourne Legal Studies Research Paper No. 723. (https://ssrn.com/abstract=2679720)

36 Nanotechnology to aid chemical and biological defence, T. A. Camesano (Ed), NATO Science for Peace and Security Series A: Chemistry and Biology, 2015, Springer, ISBN 978-94-017-7218-1.

37 See: www.opcw.org/chemical-weapons-convention/articles/article-ii-definitions-and-criteria/

8.3 In the subsequent discussion, the following points were raised:

(a) Nanotechnology was recognised as a field of development at the intersection of many fields of science, providing a good illustration of scientific convergence.

(b) The discussion on nanotechnology and its implications for the Convention served as a reminder of the need for sound scientific advice with regard to new technologies.

8.4 Professor Mongia Said Zina provided a presentation on catalysis by nanostructured materials for environmental protection. She began by explaining that catalysis was a core area of science posing fundamental and conceptual challenges, while being central to industrial chemistry and making important contributions to economic development. Catalysis plays a crucial role in research and development since it is capable of combining economic and environmental goals. The employment of catalysis is the ninth of the 12 principles of green chemistry[38] and is sometimes referred to as the "foundational pillar" of green chemistry. The role of catalysts is to create valuable materials, reduce waste, and avoid the use or production of hazardous substances. Heterogeneous catalysis has always been considered an integral part of the nanosciences. Finally, catalysis is one of the oldest known sciences that regularly employs nanomaterials.

8.5 Protecting the environment from the effects of atmospheric pollutants requires the development of highly selective and durable catalysts. These materials are designed based on nanoscale characterisation of the surface chemistry. The need to control surface structure and chemical reactivity at the nanoscale is central to research and engineering of catalysts. Exciting advances have recently occurred in the synthesis of small metal and metal oxide nanoparticles with controlled size, shape, and specific surface orientations. Currently, selectivity to form desired products without the formation of by-products is the main research challenge. Development of *in situ* spectroscopic tools and atomic-resolution electron microscopy has revolutionised the understanding of nanostructured catalysts. Furthermore, major progress has been made in characterising catalysts in their working state.

8.6 Applications in the field of nanocatalysis include catalytic combustion of methane, supported on zeolite and other nanostructured materials,[39] and bio-inspired materials

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38 The Twelve Principles of Green Chemistry: What it is & Why it Matters. (http://www.compoundchem.com/2015/09/24/green-chemistry/)

39 (a) Theoretical and experimental investigations on site occupancy for palladium oxidation states in mesoporous Al-MCM-41 materials; A. Gannouni, X. Rozanska, B. Albela, M. S. Zina, F. Delbecq, L. Bonneviot, A. Ghorbel; *Journal of Catalysis*, 2012, *289*, 227-237. DOI: 10.1016/j.jcat.2012.02.014.
(b) Metal dispersion, accessibility and catalytic activity in methane oxidation of mesoporous templated aluminosilica supported palladium; A. Gannouni, B. Albela, M. S. Zina, L. Bonneviot; *Applied Catalysis A: General*, 2013, *464–465*:, 116–127. DOI: 10.1016/j.apcata.2013.05.017.
(c) Surface engineering and palladium dispersion in MCM-41 for methane oxidation; S. Zribi, B. Albela, L. Bonneviot, M. S. Zina; *Applied Catalysis A: General,* 2015, *502*, 195-203. DOI: 10.1016/j.apcata.2015.06.015.

for CO2 valorisation and the storage of hydrogen.[40]

8.7 In the subsequent discussion, the SAB recognised that nanocatalysts were routinely used to eliminate toxic materials from some chemical processes.

8.8 Mr Valentin Rubaylo discussed the toxicology of nanomaterials with the Board. Nanoparticles have proven useful as tools for a wide variety of industrial and medical applications, including drug delivery systems. There were, however, limited details on nanoparticle-mediated toxicity. Mr Rubaylo explained that further work was required to understand the risks of oxidative stress, inflammation, and negative impact on the endocrine system resulting from nanoparticle exposure.

8.9 In the subsequent discussion, it was noted that nanoparticles and nanomaterials employed in clinical applications require nanocarrier materials that are biocompatible, limiting the consideration of certain materials.[41]

8.10 Professor Andrew Wang, guest speaker from the University of North Carolina School of Medicine, briefed the Board on developments and future directions of nanomedicines,[42] a relatively new area of interdisciplinary science. Taking nanomedicines into clinical use requires a broad range of scientific expertise; a convergence of physics, chemistry, engineering, biology, and medical science. Professor Wang discussed the collection of preclinical evidence, clinical translation of nanomedicine,[43] and reviewed clinical data from approved nanomedicine products.

8.11 In the subsequent discussion, the following points were raised:

(a) The SAB expressed its appreciation to Professor Wang for his presentation.

(b) The development of nanomedicines is a highly technical endeavour, and many in the field are of the opinion that the easy targets for translation into clinical applications have been found.

(c) There are many reports in the scientific literature about nanoparticles crossing the blood-brain barrier and targeting specific organ or cellular targets, however many of these studies are not reproducible upon clinical translation.

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40 (a) Dehydrogenation of methylcyclohexane to toluene over partially reduced Mo-SiO_2 catalysts; N. Boufaden, R. Akkari, B. Pawelec, J. L.G. Fierro, M. S. Zina, A. Ghorbel; *Applied Catalysis A: General*; 2015, *502*, 329–339. DOI: 10.1016/j.apcata.2015.05.026.
(b) Dehydrogenation of methylcyclohexane to toluene over partially reduced silica-supported Pt-Mo catalysts; N. Boufaden, R. Akkari, B. Pawelec, J. L.G. Fierro, M. S. Zina, A. Ghorbel; *Journal of Molecular Catalysis A Chemical;* 2016*, 420*, 96-106. DOI: 10.1016/j.molcata.2016.04.011.

41 Toxicity of nanoparticles and an overview of current experimental models; H. Bahadar, F. Maqbool, K. Niaz, M. Abdollahi; *Iran. Biomed;* 2016, *20 (1),* 1-11.

42 Investigational nanomedicines in 2016: a review of nanotherapeutics currently undergoing clinical trials; J. M. Caster, A. N. Patel, T. Zhang, A, Wang; *WIREs Nanomed Nanobiotechnol*; 2017, *9*, e1416. DOI: 10.1002/wnan.1416.

43 Clinical translation of nanomedicine; Y. Min, J. M. Caster, M. J. Eblan, A. Z. Wang; *Chem. Rev.*; 2015, *115 (19)*, 11147–11190. DOI: 10.1021/acs.chemrev.5b00116.

Significant problems of reproducibility of preclinical research in clinical settings is, however, not limited to nanomedicines.[44]

(d) Nanoparticles systems designed for vaccine delivery[45] in response to infectious disease or as catalytic nerve agent bioscavengers[46] have been reported, showing that the approach can be useful in the design of medical countermeasures.

(e) While drug development presents many challenges for nanoparticles, nanoparticles have also been used for diagnostic applications[47] and biodetoxification.[48]

Subitem 8(b): Monitoring activities of the Technical Secretariat

8.12 Dr Jonathan Forman updated the SAB on the Secretariat's activities in keeping abreast of science and technology developments. His presentation highlighted developments relevant to the destruction of chemical weapons, verification, and assistance and protection. In his review, Dr Forman made note of driving forces[49] that bring new developments forward, and then focused on capabilities enabled by technological advances (especially through integration of data analysis with physical measurements), noting where existing technologies with the same capabilities may already exist. Technical content of particular interest included recent reviews on chromatographic analysis of chemicals of relevance to the Convention;[50] chemical sniffing technologies;[51] the analysis of human serum albumin adducts of toxic chemicals;[52] a literature review on CBRN protective

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44 The economics of reproducibility in preclinical research; L. P. Freedman, I. M. Cockburn, T. S. Simcoe; *PLoS Biol*; 2015, *13(6)*, e1002165. DOI:10.1371/journal.pbio.1002165.

45 Particulate delivery systems for vaccination against bioterrorism agents and emerging infectious pathogen; Y. Fan, J. J. Moon; *Nanomedicine and Nanobiotechnology*; 2016. DOI: 10.1002/wnan.1403.

46 A simple and highly effective catalytic nanozyme scavenger for organophosphorus neurotoxins; E. N. Efremenko, I. V. Lyagin, N. L. KlyachkoT. Bronich, N. V. Zavyalova, Y. Jiang, A. V. Kabanov; *Journal of Controlled Release*; 2017, *247*, 175-181. DOI: 10.1016/j.jconrel.2016.12.037.

47 Nanochemistry and nanomedicine for nanoparticle-based diagnostics and therapy; Chen, I. Roy, C, Yang, P, N. Prasad; *Chem. Rev.*, 2016, *116 (5)*, 2826–2885. DOI: 10.1021/acs.chemrev.5b00148.

48 A review on nanoparticle-based technologies for biodetoxification; F. Muhammad, T. D. T. Nguyen, A. Raza, B. Akhtar, S. Aryal; *Drug Chem Toxicol.*; 2017, *31*, 1-9. DOI: 10.1080/01480545.2016.1277736.

49 OECD Science, Technology and Innovation Outlook OECD, 2016, ISBN: 9789264268081 (EPUB); 9789264263062 (PDF); 9789264263055(print). DOI: 10.1787/sti_in_outlook-2016-en. http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-innovation-outlook-2016_sti_in_outlook-2016-en

50 Chromatographic analysis of chemical compounds related to the Chemical Weapons Convention; Z. Witkiewicz, E. Sliwka, S. Neffe; *Trends in Analytical Chemistry*, 2016, *85*, 21–33. DOI: 10.1016/j.trac.2016.05.006.

51 Chemical sniffing instrumentation for security applications; S. Giannoukos, B. Brkić, S. Taylor, A. Marshall, G. F. Verbeck; *Chem. Rev.;* 2016, *116*, 8146−8172. DOI: 10.1021/acs.chemrev.6b00065.

52 Biomonitoring human albumin adducts: the past, the present, and the future; G. Sabbioni, R. J. Turesky; *Chem Res. Toxicol.;* 2017, *30 (1),* 332–366. DOI: 10.1021/acs.chemrestox.6b00366.

clothing;[53] engineered microorganisms for nerve agent destruction and sensing environmental pollutants;[54] computer vision methods for recognising diseased vegetation;[55] and progress toward developing vaccines for central nervous system-acting drugs of abuse.[56] Dr Forman discussed how we lived in a time where access to and diffusion of transdisciplinary (convergent) scientific knowledge was unprecedented, stressing that in order to provide practical technical advice we must recognise the difference between a scientific discovery and a fieldable technological capability.

8.13 During the presentation, views were provided on how the scientific developments that had been reviewed by the Secretariat and the SAB might be brought forward into the report to the Fourth Review Conference (see agenda item 13), highlighting the need to balance what was possible with practical views on the implications for the Convention.

8.14 In the subsequent discussion, the SAB thanked the Secretariat for its efforts in keeping abreast of scientific developments and for recognising where these were relevant to the Convention. The SAB considered the Secretariat's practice of providing general technology monitoring updates to be highly valuable and supported its continuation.

9. AGENDA ITEM NINE – Scientific and technological elements of verification technologies, emerging technologies, and new equipment

Subitem 9(a): OPCW Fact-Finding Mission

9.1 Mr Aamir Shouket, Deputy Chief of Cabinet, and Mr Steven Wallis, a Team Leader of the OPCW Fact-Finding Mission (FFM), reviewed the work of the

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53 Chemical, biological, radiological and nuclear (CBRN) protective clothing – a review; M. J. Magalhães, S. Tenreiro de Magalhães, H. Jahankhani; in *Global Security, Safety and Sustainability -The Security Challenges of the Connected World, Communications in Computer and Information Science*; 2017, 630, 331-341. DOI: 10.1007/978-3-319-51064-4_26.

54 (a) Engineering bacteria to catabolize the carbonaceous component of sarin: teaching *E. Coli* to eat isopropanol; M. E. Brown, A. Mukhopadhyay, J. D. Keasling, *ACS Synth. Biol*., 2016, *5 (12),* 1485-1496. DOI: 10.1021/acssynbio.6b00115.
(b) Yeast biosensors for detection of environmental pollutants: current state and limitations; S. Jarque, M. Bittner, L. Blaha, K. Hilscherova; *Trends in Biotechnology*; 2016, *34*, 408–419. DOI: 10.1016/j.tibtech.2016.01.007.

55 Using deep learning for image-based plant disease detection; S. P. Mohanty, D. P. Hughes, M. Salathé; *Front. Plant Sci.;* 2016, *7,* Article 1419. DOI: 10.3389/fpls.2016.01419.

56 (a) Combatting synthetic designer opioids: active vaccination ablates lethal doses of fentanyl class drugs; P. T. Bremer, A. Kimishima, J. E. Schlosburg, B. Zhou, K. C. Collins, K. D. Janda, A. Chem; *Intl. Ed. Engl.;* 2016, *55(11)*, 3772–3775. DOI: 10.1002/anie.201511654.
(b) Cocaine vaccine development: evaluation of carrier and adjuvant combinations that activate multiple toll-like receptors; A. Kimishima, C. J. Wenthur, L. M. Eubanks, S. Sato, K. D. Janda; *Mol. Pharmaceutics*; 2016, *13*, 3884−3890. DOI: 10.1021/acs.molpharmaceut.6b00682.
(c) Influencing antibody-mediated attenuation of methamphetamine CNS distribution through vaccine linker design; M. Gooyit, P. O. Miranda, C. J. Wenthur, A. Ducime, K. D. Janda; *ACS Chem. Neurosci.*; 2017, *8 (3)*, 468-472. DOI: 10.1021/acschemneuro.6b00389.
(d) An advance in prescription opioid vaccines: overdose mortality reduction and extraordinary alteration of drug half-life; A. Kimishima, C. J. Wenthur, B. Zhou, K. D. Janda, *ACS Chem. Biol.*; 2017, *12 (1*), 36–40. DOI: 10.1021/acschembio.6b00977.

FFM,[57,58] the Declaration Assessment Team (DAT), and the OPCW-United Nations Joint Investigative Mechanism (JIM)[59] in the Syrian Arab Republic,[60] including updates after the decision taken by the Council at its Eighty-Third Session (EC-83/DEC.5, dated 11 November 2016).[61]

9.2 In the subsequent discussion, the SAB thanked the speakers for their presentation and reaffirmed their concern and condemnation of the use of chemicals as weapons.

Subitem 9(b): Toxins

9.3 Dr Brigitte Dorner, guest speaker from the Robert Koch Institute (RKI), briefed the Board on advances in detection and identification technologies for biological toxins. She explained that biological toxins are a large group of molecules produced by living organisms (e.g. plants, animals, and bacteria) that induce harmful effects in other organisms and which, although exerting diverse functions in human cells, have several things in common:

(a) Detection of high molecular weight biological toxins is a challenge since the molecules are active in the absence of the producing organism and its genetic information. Therefore, detection at the nucleic acid level is not sufficient (other than for pathogens)—the proteins themselves have to be detected.

(b) The extraordinary toxicity of biological toxins demands detection limits down to a few pg/mL, especially for molecules like botulinum neurotoxins (BoNTs) or ricin, and when analysing clinical samples.

(c) Most challenging is the fact that biological toxins are often produced in numerous variants or isoforms that can differ in their characteristics, requiring methods to be available to distinguish them precisely. From an analytical point of view, it is necessary to ensure that no toxic variant evades recognition.

9.4 As an example of the above, *Ricinus communis* produces the plant toxin ricin in different isoforms (ricin D, ricin E) which have to be distinguished from *R. communis* agglutinin, a less toxic protein approximately 90% identical to ricin at the amino acid level. The situation with the bacterial BoNTs is much more complicated: they are

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57 Recent updates on the activities of the FFM are available in: (a) "Report of the OPCW Fact-Finding Mission in Syria Regarding the Incident of 2 August 2016 as Reported in the Note Verbale of the Syrian Arab Republic Number 69, Dated 16 August 2016" (S/1444/2016, dated 21 December 2016); and (b) "Summary Update of the Activities Carried Out by the OPCW Fact-Finding Mission in Syria in 2016" (S/1445/2016, dated 27 December 2016). Both reports are available at: http://www.un.org/ga/search/view_doc.asp?symbol=S/2017/45

58 Previous reports of the FFM are available at: https://www.opcw.org/special-sections/syria/fact-finding-mission-reports/

59 OPCW-UN Joint Investigative Mechanism Fact Sheet, available at: https://unoda-web.s3-accelerate.amazonaws.com/wp-content/uploads/2016/08/JIM-Fact-Sheet-July2016.pdf

60 Progress in the Elimination of the Syrian Chemical Weapons Programme (EC-84/DG.11, dated 24 January 2017), available at: www.opcw.org/fileadmin/OPCW/EC/84/en/ec84dg11_e_.pdf

61 Available at: www.opcw.org/fileadmin/OPCW/EC/83/en/ec83dec05_e_.pdf. See also "Status of Implementation of Executive Council Decision EC-83/DEC.5 (dated 11 November 2016)", available at: www.opcw.org/fileadmin/OPCW/EC/84/en/ec84dg25_e_.pdf

produced in eight known serotypes (A through H) and at least 40 subtypes that differ up to 36% at the amino acid level. Additionally, BoNTs are released in different high molecular weight complexes, shielded within different non-toxic proteins. A strategy to tackle the challenge of high variability and the need for ultimate sensitivity is to use a combination of methods at different technical levels: immunological, functional, and spectrometric approaches, or combinations thereof. For all protein-based detection methods, antibodies are necessary to enable immune affinity extraction from complex sample matrices, to increase sensitivity or to block observed functional effects. More than 70 high-affinity monoclonal antibodies have been generated against different biological toxins and incorporated into various technical approaches. Immunological assays are still among the most sensitive technologies (with limit of detection (LOD) near single-digit pg/mL levels), provided that high-affinity, well-characterised monoclonal antibodies are used.[62] These have successfully been used for on-site detection of biological toxins.[63] On the other hand, mass spectrometry-based techniques such as liquid chromatography-tandem mass spectrometry (LC-MS/MS) have the highest discriminatory power with unambiguous results, with detection limits around 1 ng/mL.[64] Functional methods display the enzymatic activity of biological toxins, e.g. the depurination and cytotoxic activity of ricin or the endopeptidase activity of BoNT.[65] At best, functional assays should be able to display all the different biological aspects of a toxin (e.g. cell binding plus enzymatic activity) in order to determine the potency of a given sample.

9.5 Worldwide, many different detection and identification methods for biological toxins have been described by expert laboratories. Still, key problems in the field of biological toxins include the lack of certified reference materials, the lack of accessibility of high quality detection tools and materials for validation purposes, the absence of commonly accepted standard operating procedures, and the lack of regular proficiency tests. Therefore, the comparability of different methods is currently

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62 (a) Simultaneous quantification of five bacterial and plant toxins from complex matrices using a multiplexed fluorescent magnetic suspension assay; D. Pauly, S. Kirchner , B. Stoermann, T. Schreiber, S. Kaulfuss, R. Schade, R. Zbinden, M.A. Avondet, M.B. Dorner, B.G. Dorner; *Analyst;* 2015,*134,* 2028 – 2039.
(b) Recommended immunological assays to screen for ricin-containing samples; S. Simon, S. Worbs, M.A. Avondet, D.M. Tracz, J. Dano, L. Schmidt, H. Volland, B.G. Dorner, C.R. Corbett; *Toxins;* 2015*, 7(12),*4967-4986. DOI: 10.3390/toxins7124858.
(c) Recommended Immunological Strategies to Screen for Botulinum Neurotoxin-Containing Samples; S. Simon, U. Fiebig, Y. Liu, R. Tierney, J. Dano, S. Worbs, T. Endermann, M.C. Nevers, H. Volland, D. Sesardic, M.B. Dorner; *Toxins (Basel); 2015, 7(12),*5011-5034. DOI: 10.3390/toxins7124860.

63 Simultaneous differentiation and quantification of ricin and agglutinin by an antibody-sandwich surface plasmon resonance sensor; D. Stern, D. Pauly, M. Zydek, C. Müller, M.A. Avondet, S. Worbs, F. Lisdat, M.B. Dorner, B.G. Dorner; *Biosens Bioelectron;* 2016, *15,*78,111-7. DOI: 10.1016/j.bios.2015.11.020.

64 (a) Recommended mass spectrometry-based strategies to identify botulinum neurotoxin-containing samples; S. R. Kalb, J. Baudys, D. Wang, J.R. Barr; *Toxins (Basel);* 2015*,* 7(5), 1765-1778. DOI:10.3390/toxins7051765.
(b) Detection, differentiation, and identification of botulinum neurotoxin serotypes C, CD, D, and DC by highly specific immunoassays and mass spectrometry; E. M. Hansbauer, M. Skiba, T. Endermann, J. Weisemann, D. Stern, M.B. Dorner, F. Finkenwirth, J. Wolf, W. Luginbühl, U. Messelhäußer, L. Bellanger , C. Woudstra, A. Rummel, P. Fach, B. G. Dorner; *Analyst;* 2016, *141,* 5281 – 5297.

65 Real-time cytotoxicity assay for rapid and sensitive detection of ricin from complex matrices; D. Pauly, S. Worbs, S. Kirchner, O. Shatohina, M.B. Dorner, B.G. Dorner; *PLoS One*; 2012, *7*, e35360. DOI: 10.1371/journal.pone.0035360.

limited.[66] In order to start working on these issues, from 2012 to 2014 RKI coordinated EQuATox, the European Union (EU) project that set the basis for appropriate measures in quality assurance.[67] Reference materials for biological toxins such as ricin and BoNTs have been produced and characterised by the European consortium.[68] The materials were used to organise the first proficiency tests on ricin and BoNT detection and identification, among others. Results were published in a special issue of the journal *Toxins*.[69,70] The exercises helped to define the capabilities of detection and identification technologies, revealing where technical improvements were necessary. The deficits identified will be addressed in a new European project that will start in June 2017 and integrate 57 institutions from 23 countries (EuroBioTox project–"European programme for the establishment of validated procedures for the detection and identification of biological toxins"). The programme will establish a close link with similar activities undertaken at the OPCW to join forces and to maximise the impact of results.

9.6 In the subsequent discussion, the following points were raised:

(a) The SAB expressed its appreciation to Dr Dorner for her presentation.

(b) The methods discussed represented those available to expert off-site laboratories. Dr Dorner explained that developing these methods was just as important as the on-site options, as a lateral flow assay can suffer from high rates of both false positives and false negatives.

(c) While Dr Dorner collaborates with a large number of laboratories, she indicated that very few are part of a law enforcement agency.

(d) Ricin is less toxic orally than by other routes of exposure.[71]

(e) With regard to vaccines for ricin, while a number of candidates had been developed, Dr Dorner suggested there could be value in having an expert group review the field and make recommendations for identifying a best path forward.[72]

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66 Biological toxins of potential bioterrorism risk: Current status of detection and identification technology; B. G. Dorner, R. Zeleny, K. Harju, J. A. Hennekinne, P. Vanninen, H.Schimmel, A. Rummel; *Trends in Anal Chem*; 2016, *85*, 89-102. DOI: 10.1016/j.trac.2016.05.024.

67 For more information see: www.equatox.eu/

68 Characterization of ricin and R. communis agglutinin reference materials; S.Worbs, M. Skiba, M. Söderström, M.L. Rapinoja, R. Zeleny, H. Russmann, H. Schimmel, P. Vanninen, S.A. Fredriksson, B.G. Dorner; *Toxins;* 2015*, 7(12),*4906-34*.* DOI: 10.3390/toxins7124856.

69 See: http://www.mdpi.com/journal/toxins/special_issues/detect-identi-toxins

70 An international proficiency test to detect, identify and quantify ricin in complex matrices; S. Worbs, M. Skiba , J. Bender, R. Zeleny, H. Schimmel, W. Luginbühl, B. G. Dorner; *Toxins;* 2015, *7(12),* 4987-5010. DOI: 10.3390/toxins7124859.

71 How dangerous could be the receiving of a ricin-contaminated letter?; S. Saeidnia, M.Abdollahi; *Iranian Journal of Biotechnology;* 2013*, 11(3),* 141-143.

72 Recent advances in the development of vaccines against ricin; R.N. Brey, N. J. Mantis, S. H. Pincus, E. S. Vitetta, L. A. Smith, C. J. Roy; *Human vaccines and Immunotherapeutic*; 2016, *12*, 1196-1201. DOI:10.1080/21645515.2015.1124202.

(f) In response to a query on common sources of ricin intoxication, a case study was discussed on ricin residues being found in some manure-based fertilizers; this had led to the poisoning of sheep. Published analysis of castor oils had indicated there was a low risk of ricin exposure from such oils.[73]

(g) Another toxin of potential relevance is abrin, a plant ribotoxin with a structure similar to ricin, however testing methods had not been standardised.

9.7 Mr Stuart Thomson from the OPCW Laboratory updated the SAB on the ricin sample analysis exercise that had taken place in January and February 2017.[74] The exercise had 26 participants from 19 States Parties, and 24 reports were received at the conclusion of the exercise.[75] The objectives of the exercise were to improve the capabilities of the laboratories for the analysis of ricin samples; to begin to establish recommended sample preparation and analysis methods for the unambiguous identification of ricin; to begin to establish a framework, including reporting, identification, and evaluation criteria for a future system of proficiency tests; to broaden the capability across Member States to analyse samples for biological toxins; to assess the advantages and disadvantages of different analytical methods; and to commence a discussion on acceptable criteria for the identification of biological toxins, particularly where biological functionality may need to be assessed. Mr Thomson pointed out that this exercise had not been intended to be a test of proficiency. The laboratories utilised 12 different analytical techniques, four different protein digestion regimes, and three methods to assess the biological activity. The results varied widely among the participating laboratories, demonstrating the complexity of this type of analysis and the broad range of analytical techniques employed.

9.8 In the subsequent discussion, the SAB stressed the value of such exercises and welcomed the intention to extend the work to other biotoxins in the future.

Subitem 9(c): Comprehensive Nuclear-Test-Ban-Treaty Organization International Monitoring System

9.9 Mr Patrick Grenard, guest speaker and Special Assistant to the Executive Secretary at the CTBTO, briefed the Board on the CTBTO[76] and its International Monitoring System (IMS).[77] The CTBTO had recently celebrated its twentieth anniversary, and over those 20 years 183 State Signatories had signed the Comprehensive Nuclear-Test-Ban Treaty (CTBT), of which 166 had ratified. Eight States, however, had yet to ratify the CTBT for it to enter into force. Since its inception, the CTBT

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73 Quantification of ricin, RCA and comparison of enzymatic activity in 18 *Ricinus communis* cultivars by isotope dilution mass spectrometry; D. M. Schieltz, L. G. McWilliams Z. Kuklenyik, S. M. Prezioso, A. J. Carter, Y. M. Williamson, S. C. McGrath, S. A. Morse, J. R. Barr; *Toxicon;* 2015, *95*, 72-83. http://dx.doi.org/10.1016/j.toxicon.2015.01.003

74 "Call for Nominations for an Exercise on Analysis of Ricin" (S/1422/2016, dated 16 September 2016). Available at: www.opcw.org/fileadmin/OPCW/S_series/2016/en/s-1422-2016_e_.pdf

75 See for example: https://e-reports-ext.llnl.gov/pdf/873109.pdf

76 For more on the CTBTO see: https://www.ctbto.org/

77 For more on the IMS see: https://www.ctbto.org/verification-regime/

verification regime had accumulated two decades' worth of experience and demonstrated proven results.

9.10 The CTBT verification regime includes a global system for monitoring the earth, the oceans, and the atmosphere for nuclear tests, employing seismic, hydroacoustic, infrasound, and radionuclide technologies. Over 90% of the 337 facilities making up the IMS are operational and send data to the International Data Centre (IDC) in Vienna, Austria for processing. These IMS data, along with products processed and reviewed by the IDC, are available to all CTBT Signatory States. The capabilities of the monitoring network have progressively improved as stations are added to the IMS and as IDC processing techniques are refined. Detection thresholds for seismic, hydroacoustic, infrasound, and radionuclide events have been measured and, in general, are equal to or lower than the predictions made using the original models at the time of the CTBT negotiations.

9.11 The monitoring system has demonstrated its effectiveness by detecting, locating, and reporting on the nuclear tests announced by the Democratic People's Republic of Korea in 2006, 2009, and 2013 and twice in 2016.[78] In addition to detecting radioxenon consistent with the nuclear tests in 2006 and 2013, the IMS radionuclide network showed added value in the response to the tragic events in Fukushima, Japan in 2011.[79] The CTBTO continues to find new civil and scientific applications of the IMS that are made available to the international community to deal with major societal issues, such as sustainable development, disaster risk reduction, and climate change.[80] Furthermore, the CTBT has been a catalyst for the development of new scientific fields, in particular in the infrasound and noble gas monitoring technologies. The CTBTO seeks to continuously improve its technologies and methods through interaction with the scientific community.[81]

9.12 In the subsequent discussion, the following points were raised:

(a) The SAB expressed its appreciation to Mr Grenard for his presentation.

(b) The CTBTO represents an interesting international disarmament organisation with scientific benefits, but there are also examples where the science itself and its innovations help to improve the verification aspects.

(c) Though the CTBT includes a provision for a scientific advisory board, such a board has not been activated since the CTBTO's interaction with the scientific community has so far occurred in working group B (verification issues), as well as through the scientists who are part of the monitoring network and the end-users of the data it produces.

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78 For more on IMS detection of nuclear testing in the Democratic People's Republic of Korea see: https://www.ctbto.org/the-treaty/developments-after-1996/2016-sept-dprk-announced-nuclear-test/

79 See for example: https://www.ctbto.org/press-centre/highlights/2011/fukushima-related-measurements-by-the-ctbto/

80 See for example: https://www.ctbto.org/verification-regime/spin-offs-for-disaster-warning-and-science/

81 In this regard, the CTBTO hosts a biennial science and technology conferences series. https://www.ctbto.org/the-organization/science-and-technology-the-conference-series/

Subitem 9(d): *Underworlds*

9.13 Professor Eric Alm, guest speaker from the Massachusetts Institute of Technology (MIT), introduced the Board to *Underworlds*,[82] a project in which his group collaborates with the MIT Senseable City Lab.[83] The *Underworlds* project seeks to make use of urban wastewater systems for near real-time epidemiology (with the potential for applications in early warning of disease outbreaks). The project involves collecting sewage water samples upstream from water treatment plants and performing large-scale biological and chemical analysis (detecting health-related biomarkers and metabolites). Coupling biochemical outputs with spatio-temporal information, as well as other relevant information such as demographic data, can provide insights into the aggregate health of a city. Professor Alm explained the methods of data collection (including robotic sample-collecting systems that avoid exposing humans to pathogens), data analysis, and normalisation, and how the results of such studies might be able to influence urban health policies.

9.14 In the subsequent discussion, the following points were raised:

(a) The SAB expressed its appreciation to Professor Alm for his presentation.

(b) Projects like *Underworlds* provide opportunities for recognising unusual biochemical changes in a complex environment; there is potential for detecting a chemical release, the spread of an infectious agent, and possibly metabolites of large-scale exposure to a toxic substance (where a mild level of symptoms may potentially be otherwise unrecognised).

Subitem 9(e): Inspectorate training

9.15 Mr Mehran Rouzbahani, Head of the OPCW's Inspectorate Capacity Building and Contingency Planning Cell, briefed the Board on the training programmes for both routine inspections and contingency operations. His presentation highlighted the needs for training and maintaining a fit-for-purpose Inspectorate, noting both challenges and opportunities that arise from technological change and a dynamic international security environment.

9.16 In the subsequent discussion, the following points were raised:

(a) The SAB appreciated being able to interact with the Inspectorate; the Board supported its efforts at continuous improvement and stood ready to provide technical advice if required.

(b) The SAB recognised that live-agent training and experience and knowledge of chemical reactivity were vital aspects of the skill set for an inspector. Preparing inspectors for uncertainties and unexpected situations was also thought to be valuable, and the SAB explored how the current practices best capture this aspect of preparing inspectors for field work.

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82 For more on *Underworlds* see: http://underworlds.mit.edu/

83 For more on the MIT Senseable City Lab see: http://senseable.mit.edu/

(c) The SAB was of the view that the availability of adequate resources and expertise is critical for a fit-for-purpose Inspectorate, with sound knowledge management and the transfer and retention of rare expertise being crucial in support of verification capabilities. In this regard, the SAB questioned the impact of the current tenure policy in relation to highly skilled and technically trained staff. Related to this view, Mr Rouzbahani agreed that while rare expertise must be retained, it was also valuable to balance this with new skills and perspectives that would come from new appointments.

Subitem 9(f): Computational chemistry and the Chemical Weapons Convention: Insights into the reactivity of Levinstein mustard by density functional theory

9.17 Dr Marc-Michael Blum from the OPCW Laboratory briefed the Board on how computational approaches in the study of mustard agent could inform the work of the Secretariat. He set the scene for the technical briefing with a review of recent events, noting that the FFM had been able to confirm "with utmost confidence" that at least two people had been exposed to the blister agent sulfur mustard (HD) in the town of Marea, the Syrian Arab Republic, during an attack on 21 August 2015, and that the OPCW-United Nations Joint Investigative Mechanism (JIM), in its third report to the United Nations Security Council, had attributed the Marea attack to non-State actors.[84] Additionally, Dr Blum explained that the OPCW had worked with Iraqi authorities leading to the confirmation of the use of HD in the Kurdistan Region of Iraq. As thiodiglycol (TDG), the main precursor to produce pure HD, is a highly regulated chemical, non-State actors might turn to alternative production methods that result in an impure, but still highly toxic, form of "crude" HD. One of these alternative methods is the so called Levinstein Process, in which disulfur dichloride is reacted with dry ethylene under specific conditions to directly yield HD.[85] According to a report by the JIM, the HD used in the recent incidents in northern Iraq had been produced by this process.

9.18 The final product of the Levinstein Process is an impure mixture containing about 70% HD. The two main impurities (ca. 10% ± 5% of each depending on the reaction conditions and age of the sample) are the di- and trisulfide analogues of HD: bis(2-chloroethyl) disulfide (HS2) and bis(2-chloroethyl) trisulfide (HS3). These compounds and the related higher polysulfides are also known as the "Levinstein mustards". Because of their large relative amounts, HS2 and HS3 lead to significant amounts of degradation/reaction products in the environment, resulting in unique chemical signatures. Therefore, the reactivity and potential reaction pathways of HS2 and HS3 are of significant interest, but have not been the subject of intense study

84 Third report of the Organization for the Prohibition of Chemical Weapons-United Nations Joint Investigative Mechanism (to the United Nations Security Council), United Nations document S/2016/738/Rev.1, dated 24 August 2016. Available at: http://www.un.org/ga/search/view_doc.asp?symbol=S/2016/738/Rev.1

85 The polysulfides in Levinstein process mustard gas; R. Macy, G. N. Jarman, A. Morrison, E. Emmet Reid; *Science;* 1947, *106*, 355-359. DOI: 10.1126/science.106.2755.355.

since the late 1940s.[86,87,88] In addition, the toxic properties of HS2, HS3 are of interest. Data regarding the toxicity of HS2 and HS3 is rare, but has been reported to have significantly reduced vesicant properties (1 to 2% of the vesicant impact of HD) for HS2 and no vesicant properties for HS3.[89]

9.19 Dr Blum described the use of quantum chemical methods using density functional theory (DFT)[90] as implemented in the Amsterdam Density Functional (ADF) software package[91] to study degradation pathways of HD, HS2, and HS3. Interpretation of such reaction pathways employing molecular orbital (MO) theory was able to explain the reduced reactivity of the Levinstein mustards. This reduced reactivity was also confirmed by experimental data for HS2, leading to adduct formation with the free cysteine thiol (Cys34) in human serum albumin (however, the utility as a biomarker of exposure was limited due to the extremely high concentrations that may be required for these adducts to form).

9.20 In the subsequent discussion, the following points were raised:

(a) The polysulfides observed in Levinstein mustard have value in verification, possibly identifying the production method. However, the environmental fate of these compounds had not been well characterised.

(b) The SAB expressed interest in decontamination studies that had been performed on the higher mustard compounds. Professor Roberto

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86 (a) Levinstein mustard gas. I. 2-Haloalkylsulfenyl halides; R. C. Fuson, C.C. Price, R. A. Bauman, O. H. Bullitt, W. R. Hatchard, E. W. Maynert, *J. Org. Chem.*; 1946, *11*, 469-474.
(b) Levinstein mustard gas. II. The addition of 2-chloroethylsulfenyl chloride to propylene; R. C. Fuson, C. C. Price, D. M. Burness, *J. Org. Chem.*; 1946, *11*, 475-481.
(c) Levinstein mustard gas. III. The structure of the monochlorination product of mustard gas; R. C. Fuson, W. E. Parham, *J. Org. Chem.*; 1946, *11*, 482-486.
(d) Levinstein mustard gas. IV. The bis(2-chloroethyl) polysulfides; R. C. Fuson, C. C. Price, C. M. Burness, R. E. Foster, W. R. Hatchard, R. D. Lipscomb, *J. Org. Chem.*; 1946, *11*, 487-498.
(e) Levinstein mustard gas. V. The action of chlorine and sulfur chlorides on the bis(2-chloroethyl) polysulfides; R. C. Fuson, D. M. Burness, R. E. Foster, R. D. Lipscomb, *J. Org. Chem.*; 1946, *11*, 499-503.
(f) Levinstein mustard gas. VI. The mode of formation; R. C. Fuson, R. E. Foster, R. D. Lipscomb, *J. Org. Chem.*; 1946, *11*, 504-509.

87 Hydrolysis and oxidation of mustard gas and related compounds in aqueous solution; C. C. Price, O. H. Bullitt; *J. Org. Chem.*; 1947, *12*, 238-248. DOI: 10.1021/jo01166a006.

88 The composition of mustard gas made by the Levinstein process; A. M. Kinnear, J. Harley-Mason; *J. Soc. Chem. Ind.*; 1948, *67*, 107-110. DOI: 10.1002/jctb.5000670308.

89 (a) S. Franke, *Lehrbuch der Militärchemie*; Bd.1, Deutscher Militärverlag, Berlin (Ost), 1969.
(b) The composition of Levinstein H; A. M. Kinnear, J. Harley-Mason, *Porton Report 2537*; 1943.
(c) New organic sulphur vesicants. Part IV. 1:2-Di-(2-chloroethylthio)ethane and its analogues; J. Gasson, H. McCombie, A. H. Williams, F. N. Woodward; *J. Chem Soc.*; 1948, 44-46. DOI: 10.1039/JR9480000044.

90 Investigation of Polysulfide Mustard Analogues and Reactive Intermediates from Levinstein Mustard by Density Functional Theory (DFT); M.-M. Blum. www.opcw.org/fileadmin/OPCW/Science_Technology/poster_MustardDFT.pdf

91 (a) Chemistry with ADF; G. te Velde, F. M. Bickelhaupt, E. J. Baerends, C. Fonseca Guerra, S. J. A. van Gisbergen, J. G. Snijders, T. Ziegler; *J. Comput. Chem.*; 2001, *22*, 931-967. DOI: 10.1002/jcc.1056.
(b) Towards an order-N DFT method; C. Fonseca Guerra, J. G. Snijders, G. te Velde, E.J. Baerends; *Theo. Chem. Acc.*; 1998, *99*, 391-403. DOI: 10.1007/s002140050353.

Martínez-Álvarez will provide a briefing to the Board at its Twenty-Sixth Session.

10. AGENDA ITEM TEN – Medical countermeasures, treatment, and response to chemical agents

Challenging chronic effects of sulfur mustard exposure through gene therapy

10.1 Professor Mohammad Abdollahi briefed the Board on the potential for the use of gene therapy to treat the chronic effects of HD exposure. HD toxicity proceeds through different genetic and epigenetic mechanisms,[92] and may result in pathological conditions such as skin and lung injuries and malignancies, especially in the reproductive system and blood. Understanding more about the mechanism of HD toxicity had given scientists the opportunity to work on better treatments compared to conventional methods. In this regard, gene therapy strategies had received much attention in drug development, especially in cancer due to the genetic basis of the disease. There were several clinical trials and a few approved medications in the pharmaceutical market in the field of cancer gene therapy. Cancer immunotherapy, including use of cancer vaccines, helps the immune system to fight cancerous cells. Epigenetic medications by ameliorating dysregulation of gene expression had become dominant in cancer therapy approaches; these strategies are the cornerstone of new approaches to cancer therapy and are a potential option for treatment of malignancies in HD-exposed patients.

10.2 In the subsequent discussion, the following points were raised:

(a) Exposure to mustard agents does not necessarily cause cancer. From a survey of literature data, it could be concluded that lung cancer preceded cancers of the skin, reproductive system, and blood.

(b) The mechanisms through which HD transports itself through the body and distributes across tissues and organ are complex. HD can produce a variety of degradation and reaction products that can further react with a variety of biological molecules. To this day, the precise molecular mechanism through which HD produces blisters is not understood.

11. AGENDA ITEM ELEVEN – Advice on chemicals

Updates to the Scientific Advisory Board's previous advice on riot control agents

11.1 Dr Christopher Timperley summarised the SAB's previous advice on riot control agents (RCAs).[93] The Board had recently reviewed its work from 2014, updating the original list of chemicals it had used to identify chemicals that met the criteria of an

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92 An evidence-based review of the genotoxic and reproductive effects of sulfur mustard; F. Khan. K.N. Fatima, I. Hassan, M. Abdollahi; *Arch Toxicol*; 2017, *91*, 1143-1156. DOI: 10.1007/s00204-016-1911-8.

93 Declaration of Riot Control Agents: Advice from the Scientific Advisory Board (S/1177/2014, dated 1 May 2014). Available at: www.opcw.org/fileadmin/OPCW/S_series/2014/en/s-1177-2014_e_.pdf An infographic summary of this advice is also available at: www.opcw.org/fileadmin/OPCW/Science_Technology/riot_control_agents_poster.pdf

RCA as defined by the Convention.[94] The updated list consisted of 60 chemicals including 14 chemicals that had been declared as RCAs since entry into force of the Convention; chemicals identified as potential RCAs from a list drafted by the SAB's TWG on Analytical Procedures in 2001 of "riot control agents and old/abandoned chemical weapons" to be considered for inclusion in the OPCW Chemical Agent Database (OCAD);[95] RCAs that have been researched or were available for purchase, beyond those that were already declared, according to an initial survey conducted by the Secretariat in 2013; and 13 additional chemicals recognised by the SAB as having potential RCA application. From this list, 17 chemicals had been identified as meeting the criteria of an RCA as defined by the Convention. The completed report was published as a working paper of the Twenty-Fifth Session of the SAB.[96]

11.2 In the subsequent discussion, it was indicated that the list of 17 chemicals met the criteria of an RCA as defined by the Convention. The SAB stood ready to update the list based on future developments, if instructed by the Director-General.

12. AGENDA ITEM TWELVE – Advice on chemical forensics and investigative technologies

Subitem 12(a): Chemometrics in evidence evaluation

12.1 Dr Jon Ahlinder, guest speaker from the Swedish Defence Research Agency (FOI), briefed the Board on his work in forensic statistics, a well-established scientific field whose purpose is to statistically analyse evidence in order to support legal decisions. Dr Ahlinder provided an introduction to the field and described how chemometrics could be integrated with other methods to improve the evaluation of evidence in court. One particular problem of interest is the so called "large p small n" situation (where p is the number of features and n the number of samples analysed), which had become more common with the recent advances in high-throughput analytical techniques. The presentation included a case study on the analysis of a forensic data set composed of bacterial communities from fingerprints and explained how the methods could be applied in cases related to chemical and biological threat agents.[97]

12.2 In the subsequent discussion, the SAB expressed its appreciation to Dr Ahlinder for his presentation, which provided a useful view that statistical forensic analysis requires the integration of a variety of data types, all with their own nuances and requirements for validation of that specific method. In this sense, forensic science is another example of cross-disciplinary convergence. The presentation also provided insights into the potential uses of microbiomes as data sets for identifying individuals,

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94 An RCA is defined in Article II, paragraph 7 of the Convention as "Any chemical not listed in a Schedule, which can produce rapidly in humans sensory irritation or disabling physical effects which disappear within a short time following termination of exposure".

95 Paragraph 2.5 of the Report of the Fourth Session of the Scientific Advisory Board (SAB-IV/1, dated 6 February 2001). Available at: www.opcw.org/fileadmin/OPCW/SAB/en/SABIV1_e_.pdf

96 Response to the Director-General's Request to the Scientific Advisory Board to Provide Consideration on Which Riot Control Agents are Subject to Declaration Under the Chemical Weapons Convention (SAB-25/WP.1, dated 27 March 2017). Available at: www.opcw.org/fileadmin/OPCW/SAB/en/sab25wp01_e_.pdf

97 Chemometrics comes to court: evidence evaluation of chem–bio threat agent attacks; J. Ahlinder, A. Nordgaard, S. W. Lindström; *Journal of Chemometrics*; 2015, *29(5)*, 267-276. DOI: 10.1002/cem.2699.

even from fingerprint residues. Questions were raised, however, on the temporal aspects and amount of data required for such an analysis, and in this regard several studies had been published.[98]

Subitem 12(b): Update on the formation of a temporary working group on investigative science and technology

12.3 In his response to the recommendations in the report of the Twenty-Fourth Session of the SAB, the Director-General requested that a new TWG on investigative science and technology be established in accordance with paragraph 9 of the SAB's terms of reference (Annex to C-II/DEC.10/Rev.1, dated 2 December 2004). Dr Jonathan Forman reviewed the terms of reference for this TWG with the SAB, noting that the group's work was relevant to the verification regime, especially in regard to sampling and analysis and collection and validation of information that could support the OPCW's FFM, Rapid Response and Assistance Mission, and investigations under Articles IX and X of the Convention.

12.4 The objective of this TWG would be to review science and technology relevant to investigative work, especially for the validation and provenancing (i.e. determining the chronology of ownership, custody and/or location) of evidence, and integrating multiple and diverse inputs that could allow the reconstruction of a past event. The TWG would be asked to consider a number of questions that look at identifying capabilities of value accessible to inspectors tasked with investigative work, and to identify expertise and information that the Secretariat might draw on to strengthen the outcomes of its investigative findings. In addition, the TWG may be asked to provide advice on Secretariat proposals for methodologies, procedures, technologies, and equipment for investigative purposes. The TWG is expected to hold its first meeting no later than the first quarter of 2018 and would be active for a period of two years. The terms of reference for the TWG are included as Annex 2 to this report.

12.5 In the subsequent discussion, the following points were raised:

(a) The SAB appointed Dr Veronica Borrett to be the Chairperson of the TWG. The members of the TWG would be appointed during the intersessional period before the Twenty-Sixth Session of the SAB.

(b) In addition to Secretariat staff with scientific backgrounds, having a legal perspective on how investigative scientific tools might be viewed would be valuable for this TWG. The SAB asked that staff from the Office of the Legal Adviser be available during the meetings of the TWG.

(c) The work that would be undertaken by the TWG is intended to be informative, providing advice on capabilities that have benefit to investigations and how they might be used. On request, the group would advise the Director-General

98 (a) Identifying personal microbiomes using metagenomic codes; E. A. Franzosa, K. Huang, J. F. Meadow, D. Gevers, K. P. Lemon, B. J. M. Bohannan, C. Huttenhower; *PNAS*; 2015, *112 (22)*, E2930-E2938. DOI: 10.1073/pnas.1423854112.
(b) Microbiota fingerprints lose individually identifying features over time; D. Wilkins, M.H. Y. Leung, P. K. H. Lee; *Microbiome*; 2017, *5(1)*; DOI: 10.1186/s40168-016-0209-7.

(through the SAB) on relevant work being developed within the Secretariat, especially as it relates to activities under Articles IX and X of the Convention.

Subitem 12(c): Chemical forensics and evidence management: standard operating guidelines

12.6 Mr Shawn DeCaluwe, Head of the Assistance and Protection Branch (APB), and Mr Guy Valente, Project Officer in the APB, briefed the Board on the APB's chemical forensics and evidence management initiative project (CHEMFORM) currently in development. The project seeks to produce recommended best practices (RBPs) for chemical evidence collection, including the use of automated image collection of investigation sites (including using visual imaging capabilities of portable unmanned aerial vehicles). The speakers emphasised the value of SAB input in validating the scientific integrity of the RBPs and welcomed the engagement of both the SAB members and their respective States in the development and dissemination of materials produced from the CHEMFORM project in the months ahead.

12.7 In the subsequent discussion, the following points were raised:

(a) The SAB welcomed this initiative and the training benefits it would provide. They noted that the TWG on investigative science and technology could provide a forum for further updates and advice on this initiative. The SAB noted that the objectives of the CHEMFORM programme fit with recommendations made from the June 2016 workshop on chemical forensics.[99]

(b) As current sample collection procedures within the Inspectorate had been developed around the Convention's verification regime, they may be inadequate for collecting evidence that may be later used in the reconstruction of a past event. CHEMFORM represents a way forward that could provide procedures suited to the mandate of a given mission (e.g. verification-focused sample collection or evidence collection as appropriate).

13. AGENDA ITEM THIRTEEN – Future work of the Scientific Advisory Board

Subitem 13(a): Road map of the Scientific Advisory Board's work; Subitem 13(b): Twenty-Sixth and Twenty-Seventh Sessions of the Scientific Advisory Board; Subitem 13(c): 2017 Scientific Advisory Board workshops; and Subitem 13(d) Preparation of the Scientific Advisory Board's recommendations to the Fourth Review Conference

13.1 The SAB discussed its future work. The Board will hold one additional session in 2017 and one session in 2018, as follows:

(a) Twenty-Sixth Session: 16 – 20 October 2017.

(b) Twenty-Seventh Session: to be held before June 2018.

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99 Report of the Scientific Advisory Board's Workshop on Chemical Forensics (SAB-24/WP.1, dated 14 July 2016). Available at: www.opcw.org/fileadmin/OPCW/SAB/en/sab24wp01_e_.pdf

13.2 The SAB continued its discussion of the thematic topics on which individual members will provide content for the report to the Fourth Review Conference. The SAB members will work intersessionally in correspondence groups. At the Twenty-Sixth Session of the Board, a reduced schedule of technical briefings and guest speaker presentations will allow extra time for review and discussion of the report inputs. Text for thematic topics should be available at the Twenty-Sixth Session, and the intersessional period leading up to the Twenty-Seventh Session would be used to develop the report for review at the Twenty-Seventh Session.

13.3 Working toward the SAB's report on developments in science and technology to the Fourth Review Conference, two workshops will be held in 2017, namely:

(a) a workshop on emerging and innovative technologies with relevance to the Convention, to be held from 3 to 5 July in Rio de Janeiro, Brazil. This workshop is co-organised with IUPAC, the United States National Academy of Sciences, the Brazilian Academy of Sciences, and the Brazilian Chemical Society, with partial funding provided through generous support from the EU;[100] and

(b) a workshop on trends in chemical production, planned for the first week of October 2017 in Zagreb, Croatia. Details will be forthcoming.

13.4 The report on developments in science and technology is to be issued six to nine months prior to the Fourth Review Conference so that:

(a) States Parties will be able to take the scientific advice into account when formulating national positions;

(b) States Parties will be able to discuss scientific and technological developments in preparation for the Review Conference; and

(c) the Secretariat will be able to take scientific and technological advice into account when making substantive proposals to the Review Conference. In this regard, the SAB may consider holding side events on relevant topics.

Subitem 13(e): Horizon scanning and identification of key issues in science and technology: What can we learn from a Delphi study?

13.5 During its Twenty-Fourth Session, the SAB discussed how its contribution could be strengthened by providing advice on new trends and issues to monitor during the five-year period between the Fourth and Fifth Review Conferences (possibly including issues not recognised in the thematic topics of the report to the Fourth Review Conference). Dr Jonathan Forman briefed the Board on how such an endeavour might be approached, suggesting that a Delphi study may be a path forward.[101] Recent examples that can be used to draw insights into the utility of the

100 Project III (Science and Technology: Assessment of Developments in Science and Technology) of EU Council Decision (CFSP) 2015/259, dated 17 February 2015. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2015.043.01.0014.01.ENG

101 The Delphi method involves having a group of experts anonymously reply to questionnaires, receiving the group response (and comments) in the form of a statistical representation. After this the process repeats itself, allowing respondents to rethink their responses based on the feedback from the previous round. The goal is to arrive at an expert consensus through reducing the range of responses. For more information see *Analysis of the Future: The Delphi Method*; Olaf Helmer-Hirschberg, Rand Corporation, 1967. Available at: http://www.rand.org/topics/delphi-method.html

Delphi method include the identification of "grand challenges" by the United Nations Scientific Advisory Board,[102] the gathering of expert views on biological threats,[103] and a study on the future of synthetic biology in India.[104]

13.6 Dr Forman noted that in science-assessment discussions relevant to the Chemical and Biological Weapons Conventions, questions were continually raised regarding risk and misuse potential of new technologies, yet there was often no clear way of putting these speculative dangers in perspective. With a view to identifying areas of concern and providing practical technical advice, a proposal was discussed that would entail surveying stakeholders across States Parties to identify what they perceived to be pressing science and technology issues with either beneficial or challenging implications for the Convention. The information from the survey would serve as the basis for questions for a suitable group of technical experts to rank the time frame in which a given technology might be fieldable, and to make a realistic estimate of the capability (versus the perceived capability from the survey) using the Delphi method. Such a Delphi study could identify areas where sound science advice would be beneficial to States Parties (for both validating concerns and dispelling hype) and relevant to the Convention, rather than trying to identify issues from a scientific disciplinary viewpoint.

13.7 In the subsequent discussion, the following points were raised:

(a) The usefulness of a Delphi study depends heavily on proper design of the question(s) and the choice of appropriate experts.

(b) Given the work required to perform such a study, the SAB felt it unrealistic to proceed with the goal of adding such a study to the report to the Fourth Review Conference, but that the idea could be further refined and discussed at the Board's Twenty-Sixth Session.

14. AGENDA ITEM FOURTEEN – Any other business

14.1 The SAB Chairperson bade farewell to Professor Flerida Cariño, Professor Volodymyr Zaitsev, and Professor Mongia Said Zina, whose terms of office on the Board would come to a close before the next session of the Board. He thanked all of them for their engagement and the substantive contributions they had provided to the work of the SAB.

14.2 The SAB expressed its appreciation to Shell for hosting an informative visit to its Pernis Refinery site in Rotterdam; the members of the Board also thanked the Dutch Ministry of Foreign Affairs which had helped to arrange the visit.

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102 The future of scientific advice to The United Nations: A Summary Report to the Secretary-General of the United Nations from the Scientific Advisory Board, September 2016. Available at: http://en.unesco.org/un-sab/content/un-report-calls-greater-place-science-international-decision-making

103 (a) Assessing the bioweapons threat; C. R. Watson, M. C. Watson, G. Ackerman, G. K. Gronvall; *Science;* 2015, *349(6250)*, 792-793. DOI: 10.1126/science.aab0713.
(b) Expert views on biological threat characterization for the U.S. government: A Delphi Study; C. R. Watson, M. C. Watson, G. Ackerman, G. K. Gronvall; *Risk Analysis*; DOI: 10.1111/risa.12787.

104 Exploring the Future of Synthetic Biology in India and its Probable Pathways from Infancy to Maturity; D. Sing, P. Dhar; *Curr Synthetic Sys Biol*; 2013, *1(1).* Available at: http://dx.doi.org/10.4172/2332-0737.1000106

14.3 A number of SAB members are organising and/or participating in events to mark the twentieth anniversary of the OPCW in their States Parties. Events include photo exhibitions, colloquia at designated laboratories and ministries, symposia with presentations from OPCW alumni, OPCW-focused sessions at meetings of National Authorities and national and regional chemical (and other professional) societies, oral presentations at the IUPAC World Chemistry Congress, online symposia, OPCW presentations in university lecture series, and preparation of OPCW-focused publications and editorials. The members of the SAB would keep the Secretariat informed and updated on these events as they take place over the course of the year.

14.4 In the margins of the Twenty-Fifth Session of the Board, the SAB Chairperson and Vice-Chairperson briefed States Parties on 30 March, presenting an overview of the activities of the SAB to representatives of the following States Parties: Afghanistan, Algeria, Australia, Austria, Bangladesh, Chile, Costa Rica, Cuba, Estonia, Finland, France, Germany, Guatemala, Hungary, India, Iran (Islamic Republic of), Iraq, Ireland, Japan, Malta, Mexico, the Netherlands, Norway, Pakistan, Poland, the Republic of Korea, Serbia, Slovakia, Spain, Sri Lanka, Switzerland, Tunisia, Ukraine, Venezuela (Bolivarian Republic of), the United Kingdom of Great Britain and Northern Ireland, and the United States of America.

15. AGENDA ITEM FIFTEEN – Adoption of the report

The SAB considered and adopted the report of its Twenty-Fifth Session.

16. AGENDA ITEM SIXTEEN – Closure of the session

The Chairperson closed the session at 12:30 on 31 March 2017.

Annex 1: List of Participants in the Twenty-Fifth Session of the Scientific Advisory Board

Annex 2: (English only) Terms of Reference for the Temporary Working Group on Investigative Science and Technology

Annex 1

LIST OF PARTICIPANTS IN THE TWENTY-FIFTH SESSION OF THE SCIENTIFIC ADVISORY BOARD[105]

	Participant	Institution
1.	Dr Pål Aas	Norwegian Defence Research Establishment (FFI), Kjeller, Norway
2.	Professor Mohammad Abdollahi	Tehran University of Medical Sciences, the Islamic Republic of Iran
3.	Professor Isel Pascual Alonso	University of Havana, Cuba
4.	Professor Roberto Martínez-Álvarez	Complutense University, Madrid, Spain
5.	Dr Augustin Baulig	Secrétariat général de la défense et de la sécurité nationale, Paris, France
6.	Dr Renate Becker-Arnold	BASF, Ludwigshafen, Germany
7.	Dr Veronica Borrett	BAI Scientific and Honorary Fellow, University of Melbourne, Australia
8.	Dr Christophe Curty	Spiez Laboratory, Switzerland
9.	Professor David González	Department of Chemistry, University of the Republic of Uruguay and Ministry of Education, Montevideo, Uruguay
10.	Dr Zrinka Kovarik	Institute for Medical Research and Occupational Health, Zagreb, Croatia
11.	Dr Robert Mikulak	Department of State, United States of America
12.	Dr Evandro De Souza Nogueira	Brazilian Ministry of Science, Technology, Innovation and Communications (MCTIC), Brasilia, Brazil
13.	Professor Ponnadurai Ramasami	University of Mauritius
14.	Dr Syed K. Raza	Institute of Pesticide Formulation Technology (IPFT), India
15.	Mr Valentin Rubaylo	State Scientific Research Institute of Organic Chemistry and Technology, Russian Federation
16.	Professor Ahmed E. M. Saeed	Sudan University of Science and Technology, Khartoum, Sudan
17.	Dr Koji Takeuchi	National Institute of Advanced Industrial Science and Technology (AIST), Japan
18.	Mr Cheng Tang[106]	Office for the Disposal of Japanese Abandoned Chemical Weapons, Ministry of National Defence, China
19.	Dr Christopher Timperley[107]	Defence Science and Technology Laboratory (Dstl), Porton Down, United Kingdom of Great Britain and Northern Ireland
20.	Professor Ferruccio Trifirò	Department of Industrial Chemistry, University of Bologna, Italy

105 Professor Flerida Arsciwals Cariño was not able to attend the Twenty-Fifth Session of the SAB.

106 Vice-Chairperson of the SAB.

107 Chairperson of the SAB.

	Participant	Institution
21.	Mr Francois Mauritz van Straten	Chemical Weapons Working Committee, South Africa
22.	Ms Farhat Waqar	Pakistan Atomic Energy Commission
23.	Professor Volodymyr Zaitsev	Taras Shevchenko National University of Kyiv, Ukraine
24.	Professor Mongia Said Zina	Faculty of Sciences of Tunis, Tunisia
25.	Dr Jon Ahlinder (guest speaker)	Swedish Defence Research Agency (FOI), Umeå, Sweden
26.	Professor Eric Alm (guest speaker)	Massachusetts Institute of Technology, Cambridge, United States of America
27.	Dr Mark Cesa (guest speaker)	International Union of Pure and Applied Chemistry
28.	Dr Brigitte Dorner (guest speaker)	Robert Koch Institute, Berlin, Germany
29.	Mr Patrick Grenard (guest speaker)	Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria
30.	Professor Andrew Wang (guest speaker)	University of North Carolina at Chapel Hill, Chapel Hill, United States of America

Annex 2

TERMS OF REFERENCE FOR THE TEMPORARY WORKING GROUP ON INVESTIGATIVE SCIENCE AND TECHNOLOGY

1. The ongoing contingency operations of the Technical Secretariat have increasingly involved investigations, analysis, and fact-finding, with collection and evaluation of oral, material, and digital evidence of the use of chemical agents. Such activities are not part of routine inspection and verification activities under the Chemical Weapons Convention. The Director-General has decided that it would be useful to have an in-depth review of the methods and technologies used in investigative work, and that these would be relevant to and augment the capacity of the Technical Secretariat. Further to his response to the report of the Twenty-Fourth Session of the SAB (SAB-24/1, dated 28 October 2016) and in accordance with paragraph 9 of the terms of reference of the SAB (Annex to C-II/DEC.10/Rev.1, dated 2 December 2004), the Director-General has therefore established a Temporary Working Group (TWG) on Investigative Science and Technology and has appointed Dr Veronica Borrett as the Chairperson of the Group.

2. The objective of the TWG is to review the science and technology relevant to investigations such as those mandated under Articles IX and X of the Chemical Weapons Convention. This would include science and technology for the validation and provenancing (i.e. determining the chronology of ownership, custody and/or location) of evidence, and the integration of multiple and diverse inputs to reconstruct a past event, as well as further considerations of topics in the recommendations from the SAB's 2016 chemical forensics workshop (SAB-24/WP.1, dated 14 July 2016), and topics falling under subparagraphs 2(e)[108] and 2(g)[109] of the SAB's terms of reference. The work of this TWG is intended to identify capabilities, skill sets, and equipment that would augment and strengthen the Technical Secretariat's capabilities. The findings will be considered by the SAB and recommendations will be provided to the Director-General.

3. The TWG will consist of individuals who collectively have expertise in the theory and practice of investigative work, including but not limited to investigational chemical analysis, evidence collection, forensic sciences, informatics, crime scene reconstruction, toxicology, inspection, or experience of implementation of the Chemical Weapons Convention. Qualified members of the SAB may join the TWG. Members of relevant scientific and international organisations may also be invited to join the TWG. Guest speakers may be invited from time to time. The TWG may also, when necessary, draw upon the expertise of the Technical Secretariat, in particular the OPCW Laboratory, Inspectorate, and the Assistance and Protection Branch.

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108 "… assess the scientific and technological merit of a present, or proposed, methodology for use by the Technical Secretariat in verification under the Convention".

109 "assess and report on emerging technologies and new equipment which could be used on verification activities".

4. The TWG will report to the SAB, and will consider the following questions in particular:

   (a) Which methods and capabilities used in the forensic sciences could usefully be developed and/or adopted for the Chemical Weapons Convention-based investigations?

   (b) What are the best practices and analysis tools used in the forensic sciences for effectively cross-referencing, validating, and linking together information related to investigation sites, materials collected/analysed, and individuals interviewed?

   (c) What are the best practices for management of data collected in investigations, including compilation, curation, and analytics?

   (d) What are the best practices for the collection, handling, curation and storage, and annotation of evidence?

   (e) Which technologies and methodologies (whether established or new) allow point-of-care and non-destructive measurements at an investigation site to help guide evidence collection?

   (f) Which technologies and methodologies (whether established or new) can be used in the provenancing of chemical and/or material samples collected in an investigation?

   (g) Which methods are available (or are being developed) for the sampling and analysis of environmental and biomedical materials and can be used in the detection of toxic industrial chemicals relevant to the Chemical Weapons Convention?

   (h) Which technologies and methodologies (whether established or new) can be used in ensuring chain of custody and verifying authenticity (especially in regard to digital images and video recordings)?

   (i) Which technologies and methodologies (whether established or new) can be used to ensure the integrity of an investigation site?

   (j) Do collections of physical objects, samples, and other information for chemical weapons-related analysis exist and can they be made available to investigators for retrospective review? How might these collections be used to support investigations?

   (k) Are there stakeholders that the Technical Secretariat could usefully engage with to leverage their capabilities on investigative matters?

5. In addition, the TWG will provide advice on Technical Secretariat proposals for methodologies, procedures, technologies, and equipment for investigative purposes.

6. The Director-General might pose other relevant questions to the TWG, through the SAB.

7. The TWG will exist for a period of two years from the date of its first meeting. Thereafter, its work will be reviewed by the SAB and the Director-General, and a decision will be made as to whether it should continue its work and, if so, whether these terms of reference should be revised.

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