OPCW Scientific Advisory Board

Twenty-Seventh Session
19 – 23 March 2018

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REPORT OF THE SCIENTIFIC ADVISORY BOARD AT ITS TWENTY-SEVENTH SESSION 19 – 23 MARCH 2018

1. AGENDA ITEM ONE – Opening of the session

1.1 The Scientific Advisory Board (SAB) met for its Twenty-Seventh Session from 19 to 23 March 2018 at the OPCW Headquarters in The Hague, the Netherlands. The Session was chaired by Dr Christopher Timperley, with Mr Cheng Tang as Vice-Chairperson.

Executive summary

1.2 The SAB received three guest presentations and was provided with updates from units across the Technical Secretariat (hereinafter "the Secretariat") to help facilitate the development of recommendations that the Board is to submit to the Fourth Review Conference.[1]

1.3 At the session, final inputs were received and final recommendations were developed for the SAB's report on science and technology for the Fourth Review Conference.

2. AGENDA ITEM TWO – Adoption of the agenda

The SAB adopted the following agenda for its Twenty-Seventh 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 Deputy Director-General
6. Overview of developments at the OPCW since the last session of the Scientific Advisory Board
   (a) General updates
   (b) Education and outreach
   (c) Declarations Branch
   (d) The future of industry verification
   (e) OPCW contingency operations
   (f) Challenges of old chemical weapons and verification
   (g) Rapid Response and Assistance Mission (RRAM)
   (h) Interagency cooperation
7. Advice on chemicals
   (a) Report from the Spiez Laboratory Schedule 1 Users Forum
   (b) Shutting down a Schedule 1 facility
   (c) Modern concepts and tools for synthetic design
8. Developments in science and technology
   (a) Monitoring activities of the Technical Secretariat
   (b) A transatlantic perspective on 20 emerging issues in biological engineering
9. Scientific and technological elements of verification technologies, emerging technologies, and new equipment
   (a) Dissemination of toxic chemicals – Can biosensors serve as detectors?
   (b) "If Plants Could Talk": an artificial intelligence application
   (c) Update from the OPCW Laboratory
   (d) Host-based early warning of biological agent exposure
10. Chemical forensics and investigative technologies
    (a) First meeting and report of the temporary working group on investigative science and technology
    (b) Investigation of a chemical agent incident

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

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11. Future work of the Scientific Advisory Board

    (a) The road to the Fourth Review Conference

    (b) Roadmap of the Scientific Advisory Board's work

    (c) The Twenty-Eighth Session of the Scientific Advisory Board

    (d) The Scientific Advisory Board's report to the Fourth Review Conference

    (e) Publications of the work of the Scientific Advisory Board

12. Drafting of report of the Twenty-Seventh Session of the Scientific Advisory Board

13. Drafting of report to the Fourth Review Conference

14. Any other business

    (a) Discussion with the Director-General

    (b) Visit to the OPCW Laboratory and Equipment Store

    (c) Election of the Chairperson and Vice-Chairpersons

    (d) Departing SAB members

    (e) Briefing to States Parties

    (f) Acknowledgements

15. Adoption of reports

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 and guests. Four new members—Professor Vladimir Dimitrov (of Bulgaria), Dr Daan Noort (of the Netherlands), Professor Syeda Sultana Razia (of Bangladesh), and Dr Yasuo Seto (of Japan)—attended their first session of the SAB. A list of participants appears in the annex to this report.

4. AGENDA ITEM FOUR – Establishment of a drafting committee

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

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

5.1 The Deputy Director-General of the OPCW delivered the welcome address,[2] thanking the SAB for its contributions to the implementation of the Chemical Weapons Convention (hereinafter "the Convention") and expressing appreciation for the forward-looking emphasis that has guided the Board's science review. Looking to the upcoming Fourth Review Conference, the Deputy Director-General reflected on changes that have taken place in the OPCW's operating environment since the entry into force of the Convention. He highlighted the need for technical capabilities that were unforeseen when the Convention took shape. Non-routine missions in challenging operating environments frequently require tools and methods to detect and identify chemicals outside the schedules. The Deputy Director-General noted the value of the SAB's transdisciplinary approach to identifying how capabilities might be enhanced.

5.2 Emphasising that the OPCW stands to benefit from the technical opportunities that advancements in science can offer, the Deputy Director-General stressed the need to remain vigilant of future threats. A focus on scientific benefits must not come at the expense of recognising and preparing for new challenges. In this regard, he praised the Board for seeking to identify approaches to recognise unexpected signatures as a means to ensure that the science review does not become too narrowly focused on interesting yet unproven technology. The Deputy Director-General also recognised the Board's value to the OPCW beyond purely a science advisory function, noting that with members from 25 States Parties, the output and science diplomacy of the Board upholds the Convention's core values of international cooperation and science for peace.

5.3 Turning back to the expectations for the report to the Fourth Review Conference, the Deputy Director-General looked to the SAB to provide thought-provoking advice for States Parties to consider.

5.4 In closing, he welcomed the new members of the Board and thanked the outgoing SAB members.

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-Sixth Session. He briefly highlighted recent destruction milestones in Libya[3] and Iraq,[4] and noted several technical assistance requests.[5] Turning to the work of the

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2 The full statement is available at: www.opcw.org/fileadmin/OPCW/DDG/2018/26.IEC.OD.DG.SPEECH.SAB27.WEB.pdf.

3 Status of the Implementation of the Plan for the Destruction of Libya's Remaining Category 2 Chemical Weapons Outside the Territory of Libya (EC-87/DG.6, dated 22 December 2017): www.opcw.org/fileadmin/OPCW/EC/87/en/ec87dg06_e_.pdf.

4 Completion by Iraq of the Destruction of its Chemical Weapons Remnants (EC-87/DG.18, dated 28 February 2018).

SAB, Dr Forman reviewed the Director-General's response to the report of the Twenty-Sixth Session of the SAB,[6] and highlighted the accomplishments of the Board in 2017. This included five reports,[7] the completion of the international workshop series,[8] the further development of highly interactive and well received engagement with States Parties,[9] participation in a side-event on central-nervous system (CNS) acting chemicals,[10] a plenary statement to the Twenty-Second Session of the Conference of the States Parties (hereinafter "the Conference"),[11] and participation in

5 (a) United Kingdom of Great Britain and Northern Ireland Request for Circulation of a Document at the Eighty-Seventh Session of the Executive Council (EC-87/NAT.7, dated 14 March 2018); (b) Report of the Technical Assistance Visit to Iraq (S/1559/2017, dated 6 December 2017).

6 Response to the Report of the Twenty-Sixth Session of the Scientific Advisory Board (EC-87/DG.11, dated 25 January 2018), www.opcw.org/fileadmin/OPCW/SAB/en/ec87dg11_e_.pdf.

7 These were (1) 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), www.opcw.org/fileadmin/OPCW/SAB/en/sab25wp01_e_.pdf. (2) Report of the Scientific Advisory Board at its Twenty-Fifth Session (SAB-25/1*, dated 31 March 2017), www.opcw.org/fileadmin/OPCW/SAB/en/sab2501_e_.pdf. (3) Report of the Scientific Advisory Board's Workshop on Emerging Technologies (SAB-26/WP.1, dated 21 July 2017), www.opcw.org/fileadmin/OPCW/SAB/en/sab26wp01_SAB.pdf. (4) Report of the Scientific Advisory Board's Workshop on Trends in Chemical Production (SAB-26/WP.2, dated 19 October 2017), www.opcw.org/fileadmin/OPCW/SAB/en/sab-26-wp02_e_.pdf. (5) Report of the Scientific Advisory Board at its Twenty-Sixth Session (SAB-26/1, dated 20 October 2017), www.opcw.org/fileadmin/OPCW/SAB/en/sab-26-01_e_.pdf. A quick reference summary of work of the SAB in 2017 is available at www.opcw.org/fileadmin/OPCW/SAB/en/OPCW_SAB_in_2017.pdf.

8 These were: (1) "Chemical Forensics: Capabilities across the Field and the Potential Applications in Chemical Weapons Convention Implementation", held from 20 to 22 June 2016 in Helsinki, Finland; (2) "Chemical Warfare Agents: Toxicity, Emergency Response and Medical Countermeasures", held from 26 to 27 September 2016 in Paris, France; (3) "Innovative Technologies for Chemical Security", held from 3 to 5 July 2017 in Rio de Janeiro, Brazil; and (4) "International Workshop on Trends in Chemical Production", held from 3 to 5 October in Zagreb, Croatia. For a quick reference summary, see www.opcw.org/fileadmin/OPCW/SAB/en/2016-2017-Science_Review_Workshops_of_the_OPCW_SAB.pdf.

9 For example, the Science for Diplomats event on the SAB's Trends in Chemical Production Workshop held on the margins of the Twenty-Second Session of the Conference. For more information see (a) introduction, www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/20171129_Science_Diplomats_Trends_Chem_Production-Intro.pdf; (b) presentation by SAB Vice-Chairperson Mr Cheng Tang, www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/20171129_CTang_Science_Diplomats_Trends_Chem_Production-Presentation.pdf; (c) event poster, www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/Science_for_Diplomats_at_CSP-22.pdf; and (d) activity card, www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/Science_for_Diplomats-Ice_cream_in_a_bag-29_November_2017.pdf. Additional information on the Science for Diplomats Initiative can be found at: www.opcw.org/special-sections/science-technology/science-for-diplomats/.

10 For further information see: (a) briefing by SAB Chairperson www.opcw.org/fileadmin/OPCW/SAB/en/SAB_Chair_Presentation_at_CSP22_Side_Event_on_CNS-Acting_Chemicals.PDF; and (b) a compiled summary of SAB advice on CNS acting chemicals www.opcw.org/fileadmin/OPCW/SAB/en/SAB_Considerations_on_CNS-Acting_Chemicals_2003-2017.pdf.

11 The statement and accompanying slides are available at: www.opcw.org/fileadmin/OPCW/SAB/en/SAB_Chair_Remarks_to_CSP22-As_Delivered__2_.pdf (statement) and www.opcw.org/fileadmin/OPCW/SAB/en/SAB_Chair_Slides_for_CSP22.pdf (slides).

a workshop to launch the 2017 edition of the VERIFIN Bluebook.[12]

6.2 Dr Forman continued with updates on science and technology-related engagement of the Secretariat that included a green chemistry workshop held at the OPCW in November 2017,[13] a presentation on the convergence of the sciences at the Second World Organisation for Animal Health (OIE) Biological Threat Reduction Meeting in October 2017 in Ottawa, Canada,[14] a briefing to the Nineteenth Annual Meeting of National Authorities of States Parties to the Convention, a side event at the 2017 Biological Weapons Convention Meeting of States Parties in December 2017 in Geneva, Switzerland,[15] and the Director-General's address to the International Activities Committee of the American Chemical Society (ACS) in March 2018.[16] Ahead of the Fourth Review Conference in November 2018, Dr Forman informed the Board of several upcoming scientific conferences of relevance in which the Secretariat and/or SAB members would participate. These include the Third Green & Sustainable Chemistry Conference,[17] the American Thoracic Society International Conference in May 2018,[18] the International Union of Pure and Applied Chemistry (IUPAC) Postgraduate Summer School on Green Chemistry in July 2018,[19] the Biological Weapons Convention Meeting of Experts in August 2018, the 2018 ACS autumn meeting, which will include the second workshop of the Chemical Forensics International Technical Working Group (CFITWG) in August, the Australia and New Zealand Forensic Science Society's Twenty-Fourth International Symposium on the Forensic Sciences in September 2018,[20] the Eighth IUPAC International Conference on Green Chemistry,[21] and the Third Spiez Convergence Workshop[22] and the Tenth Congress of Chemical Sciences, Technology and Innovation, which SAB member Professor Isel Alonso is helping organise in October 2018 in Havana, Cuba.[23]

12 "Recommended operating procedures for analysis in the verification of chemical disarmament 2017 Edition". P. Vanninen (ed); University of Helsinki, Finland, 2017. For further information see http://www.helsinki.fi/verifin/bluebook/. SAB Chairperson remarks from book launch are available at www.opcw.org/fileadmin/OPCW/SAB/en/SAB_Chair_Opening_Remarks_to_VERIFIN_Workshop_on_Analysis_of_Chemical_Warfare_Agents.pdf.

13 OPCW News Item, "Experts discuss role of OPCW in green and sustainable chemistry", www.opcw.org/news/article/experts-discuss-role-of-opcw-in-green-and-sustainable-chemistry/.

14 The presentation from the OIE Biothreat Reduction Conference is available at: www.oie.int/eng/BIOTHREAT2017/Presentations/3.2_FORMAN-presentation.pdf.

15 The presentation from 2017 Biological Weapons Convention Meeting of States Parties: https://www.unog.ch/80256EDD006B8954/(httpAssets)/00013D3854D8A072C12581FC0027D947_file/20171205_BWC_MSP_OPCW-Final-print.pdf.

16 The Director-General's remarks are available at: www.opcw.org/fileadmin/OPCW/ODG/dgmcw/180319_FR_ODG_SPH_ACS_WEB.pdf.

17 For further information see: https://www.elsevier.com/events/conferences/green-and-sustainable-chemistry-conference/about.

18 For further information see: http://conference.thoracic.org/.

19 For further information see: http://www.unive.it/pag/29448/.

20 For further information see: http://www.anzfss2018.com/.

21 For further information see: http://www.greenitupac2018.com/welcome_index.html.

22 For further information see: https://www.labor-spiez.ch/en/rue/ezruesc.htm.

23 For further information see: http://www.chemistrycuba.com/.

Subitem 6(b): Education and Outreach

6.3 The Secretary to the Advisory Board on Education and Outreach (ABEO), Dr Alexander Kelle, briefed the SAB on developments related to the ABEO,[24] focussing on its report on the role of education and outreach in preventing the re-emergence of chemical weapons that had recently been submitted to the Director-General.[25] The ABEO mandate was to identify best practices and the latest advances in education and outreach theory and practice relevant to the OPCW's education and outreach activities, to relate the relevant education and outreach theory and practice to the OPCW's mandate and main areas of work as the Organisation moves its focus to preventing the re-emergence of chemical weapons, and to develop on this basis a portfolio of specific education and outreach activities and projects that the Organisation, States Parties, and the ABEO and its individual members should pursue as a matter of priority from 2018 onward.

6.4 Dr Kelle noted the key recommendations from the report and discussed follow-up activities. The latter included a further request from the Director-General to the ABEO to convert Annex 2 of its report into an easy-to-use brochure for States Parties, as well as the ongoing work in the Secretariat to complete its strategic plan for education and outreach. The ABEO held its Fifth Meeting in February 2018[26] and will meet again in August 2018.

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

(a) Programmes with regional and local focus can benefit from the work of the ABEO. Engagement of the ABEO with local audiences (including the use of local language materials) was an area that might interest many National Authorities.

(b) The recommendations of the ABEO address broader audiences than purely scientific communities. This broader engagement must be maintained in order to achieve the success intended by the ABEO's proposals.

(c) The SAB expressed an interest in education and outreach issues and is willing to contribute when opportunities permit.

Subitem 6(c): Declarations Branch

6.6 Mr Alejandro Hernandez (Head Data Analytics, Reporting and Quality Control Section of Declarations Branch in the OPCW Verification Division) briefed the SAB on tools being developed to help States Parties to comply more efficiently with their obligations under the Convention. This briefing covered analysis tools used internally to process

[24] For general information on the ABEO see: https://www.opcw.org/about-opcw/subsidiary-bodies/advisory-board-on-education-and-outreach/. For the work of the ABEO in 2017, see Report on the Activities of the Advisory Board on Education and Outreach in 2017 (EC-86/DG.29 C-22/DG.17, dated 4 October 2017), www.opcw.org/fileadmin/OPCW/EC/86/en/ec86dg29_c22dg17_e_.pdf.

[25] Report on the Role of Education and Outreach in Preventing the Re-Emergence of Chemical Weapons (ABEO-5/1, dated 12 February 2018), www.opcw.org/fileadmin/OPCW/ABEO/abeo-5-01_e.pdf.

[26] Report of the Fifth Session of the Advisory Board on Education and Outreach (ABEO-5/2, dated 1 March 2018).

the data received from declarations, and the results of a survey recently conducted across the States Parties. Enterprise content management, electronic declarations,[27] the secure exchange of information,[28] and data analytics were also described.

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

(a) The OPCW has acquired a significant amount of information over its history. The tools being developed will serve to allow more efficient use of this data by the Secretariat.

(b) Currently, 96% of declarable plant sites are submitted using electronic tools. These tools, however, are inconsistently adopted by States Parties and it would be desirable to have consistency across all States Parties that use electronic tools for declarations. SAB members responsible for declarations under the Convention commented that uniformity of data was important for the OPCW and encouraged the Secretariat to continue its efforts to assist States Parties to adopt the most current version of the tools available.

(c) Changes to declaration tools can be a burden for States Parties. The need for up-to-date and friendlier user manuals was identified as an important aspect to ensure that States Parties would be willing to move to updated tools. An e-learning tool would be well suited to help in this regard.

(d) The development of a structure searching feature within the electronic tools was noted by several SAB members as being useful, as not all declared scheduled chemicals would have been assigned a Chemical Abstracts Service registry number.

Subitem 6(d): The future of industry verification

6.8 Ms Barbara Hedler (OPCW Industry Verification Branch) briefed the SAB on developments and changes to industry verification under the Convention since the Third Review Conference. She explained how, with risk assessments undertaken, industry inspections are conducted in an effective, efficient, and consistent manner at relevant facilities with a balanced geographical distribution, and how the Organisation has identified options for adapting the verification regime to changing risk patterns, including dialogue with and among States Parties and their chemical industries.[29]

[27] Electronic Submission of Annual Declaration on Past Activities as at 31 May 2017 (S/1503/2017, dated 16 June 2017), www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1503-2017_e_.pdf.

[28] Update on the Secure Information Exchange System (S/1529/2017/Rev.1, dated 19 September 2017), www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1529-2017_e_.pdf.

[29] Refinements in the Conduct of Inspections to Improve the Consistency, Effectiveness, and Efficiency of the Article VI Verification Regime (S/1066/2013, dated 11 February 2013), www.opcw.org/fileadmin/OPCW/S_series/2013/en/s-1066-2013_e_.pdf.

6.9 Ms Hedler discussed the formal risk assessment and risk-based selection methodology[30] that is used to help focus inspections at the most relevant plant sites, as well as new analytical tools—including portable and hand-held detectors—that have been utilised in a number of Article VI inspections. Whilst industry verification efforts have assisted National Authorities in fully implementing the provisions of the Convention within their State Party, discussions (including amongst National Authorities,[31] within the chemical industry, the Open-Ended Working Groups on Future Priorities and the Fourth Review Conference (OEWG-FP and OEWG-RC), in the Industry Cluster, and on the recommendations from the SAB) have identified areas for further development. Some States Parties have encouraged the development of a more risk-based approach, such as that described in the OPCW's Vision Paper[32] and the 2017 – 2021 Medium-Term Plan.[33]

6.10 The Secretariat has also been exploring the recommendations in the reports from the SAB temporary working groups (TWG) on the convergence of chemistry and biology[34] and verification.[35] Consideration has been given to more analytical approaches, adopting consistent approaches to the declaration of facilities producing complex mixtures of discrete organic chemicals (DOCs),[36] the verification aspects of "production by synthesis", the effective use of sampling and analysis, and relevant developments in science and technology, such as those discussed at the SAB's workshop on trends in chemical production.[37]

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30 Report on the Performance of the Revised Methodology for the Selection of other Chemical Production Facilities for Inspection (S/1582/2018, dated 12 February 2018). www.opcw.org/fileadmin/OPCW/S_series/2018/en/s-1582-2018_e.pdf

31 Report of the Nineteenth Annual Meeting of National Authorities (S/1592/2018, dated 26 February 2018), www.opcw.org/fileadmin/OPCW/S_series/2018/en/s-1592-2018_e_.pdf.

32 The OPCW in 2025: Ensuring a World Free of Chemical Weapons (S/1252/2015, dated 6 March 2015), www.opcw.org/fileadmin/OPCW/S_series/2015/en/s-1252-2015_e_.pdf.

33 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): www.opcw.org/fileadmin/OPCW/EC/83/en/ec83s01_c21s01_e_.pdf.

34 Convergence of Chemistry and Biology: Report of the Scientific Advisory Board's Temporary Working Group (SAB/REP/1/14, dated June 2014), www.opcw.org/fileadmin/OPCW/SAB/en/TWG_Scientific_Advisory_Group_Final_Report.pdf. A quick reference guide to the recommendations of the TWG on the convergence of chemistry and biology is available at: www.opcw.org/fileadmin/OPCW/SAB/en/Convergence_of_Chemistry_and_Biology_1-01.pdf.

35 Verification, Report of the Scientific Advisory Board's Temporary Working Group (SAB/REP/1/15, dated June 2015): www.opcw.org/fileadmin/OPCW/SAB/en/Final_Report_of_SAB_TWG_on_Verification_-_as_presented_to_SAB.pdf. A quick reference guide to the recommendations of the TWG on the verification is available at: www.opcw.org/fileadmin/OPCW/SAB/en/VER_Poster_5102015.pdf.

36 A DOC is defined in paragraph 4 of Part 1 of the Convention's Verification Annex as "any chemical belonging to the class of chemical compounds consisting of all compounds of carbon except for its oxides, sulfides and metal carbonates, identifiable by chemical name, by structural formula, if known, and by Chemical Abstracts Service registry number, if assigned". www.opcw.org/chemical-weapons-convention/annexes/verification-annex/part-i.

37 Report of the Scientific Advisory Board's Workshop on Trends in Chemical Production (SAB-26/WP.2, dated 19 October 2017), www.opcw.org/fileadmin/OPCW/SAB/en/sab-26-wp02_e_.pdf.

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

(a) Risk assessments are important, but can be difficult to undertake. It might be useful for the Secretariat to work with National Authorities to evaluate suitable methods.

(b) Some stakeholders are asking why changes to the Article VI regime are being considered. Maintaining industry engagement on these issues with States Parties is important.

(c) In taking forward SAB recommendations on industry verification, it is useful to consider what results are intended and how they can be evaluated.

(d) Several States Parties would like to see the Secretariat assess the feasibility of converting a biomediated production facility to one that can produce chemicals of concern to the Convention, in accordance with recommendation 19 of the TWG on the convergence of chemistry and biology.[38] The SAB expressed its willingness to assist the Secretariat on this task if desired.

(e) Concerns about inspections of facilities employing biomediated processes have been raised due to intellectual property issues.

(f) For chemical security, the distribution systems for chemical products could be one of the most vulnerable aspects, and should be considered in security discussions.

Subitem 6(e): OPCW contingency operations

6.12 Mr Nihad Alihodzic (Head of the OPCW Declarations Assessment Team) provided the Board with an update on OPCW contingency operations including the ongoing work in the Syrian Arab Republic,[39] recent inspections at the Scientific Studies and Research Centre (SSRC),[40] destruction of chemical weapons production facilities,[41]

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38 Recommendation 19: "The Technical Secretariat should review the technical feasibility of converting a bio-based chemical processing facility to produce chemicals of concern to the Chemical Weapons Convention".

39 For a recent update, see: Progress in the Elimination of the Syrian Chemical Weapons Programme (EC-88/DG.1, dated 23 March 2018). Additional information related to the work of OPCW in the Syrian Arab Republic can be found at: www.opcw.org/special-sections/syria.

40 (a) Status of Implementation of Executive Council Decision EC-83/DEC.5 (dated 11 November 2016 (EC-84/DG.25, dated 6 March 2017), www.opcw.org/fileadmin/OPCW/EC/84/en/ec84dg25_e_.pdf; (b) First Inspections at the Barzah and Jamrayah Syrian Scientific Studies and Research Centre Facilities in Syrian Arab Republic in Accordance with Decision EC-83/DEC.5 (dated 11 November 2016); (EC-85/DG.16, dated 2 June 2017); (c) Status of Implementation of Executive Council Decision EC-83/DEC.5 (dated 11 November 2016) (EC-87/DG.15, dated 23 February 2018); and (d) Report by the Director-General: Status of Implementation of Executive Council Decision EC-83/DEC.5, dated 11 November 2016, and Addendum (EC-87/DG.15/Add.1, dated 28 February 2018).

41 Request by the Syrian Arab Republic for Assistance with the Destruction of its Chemical Weapons Production Facilities (S/1541/2017, dated 9 October 2017), www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1541-2017_e_.pdf.

the outcome of a recent technical assessment visit,[42] updates on the work of the Declarations Assessment Team (DAT)[43] and Fact-Finding Mission (FFM),[44] as well as general updates on the Secretariat's contingency operations.

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

(a) Contingency operations continue to present new challenges and experiences. The SAB stands ready to provide scientific advice to support the Secretariat as necessary. The work of the TWG on investigative science and technology is particularly relevant.

(b) The SAB noted that samples collected and analysed during contingency operations are important beyond the operation itself. The data generated helps to build datasets for method validation and retrospective analysis.

Subitem 6(f): Challenges of old chemical weapons and verification

6.14 Mr Sven Devroe (OPCW Chemical Demilitarisation Branch) briefed the SAB on the recent work of Secretariat on the disposal of old chemical weapons (OCW). Mr Devroe noted that since the entry into force of the Convention, 17 States Parties have declared OCW, with 11 declaring small numbers of individual munitions.

6.15 The OCW items discovered are often fused, damaged and corroded, posing an explosive and chemical risk. For highly degraded munition casings, identification of the OCW and its possible chemical fill is difficult. For this reason the Secretariat is often requested to provide technical assistance to help identify suspected items prior to declaration. Assistance in identifying and disposing of a small number of items of recovered OCW, abandoned chemical weapons (ACW) or sea-dumped chemical weapons is expected to be an ongoing need for the Secretariat, with the potential for items found from clandestine activity adding to the workload, if chemical threats continue to arise from non-State actors.

6.16 Although mobile destruction technologies are available for the destruction of only a handful of items, their costs may be prohibitive for a State Party. Complicating this situation is the fact that certain fused and armed OCW items are dangerous to transport and must be destroyed on-site. To illustrate the challenges involved,

42 Report on the Special Mission Conducted in Response to the Requests and Information Received from the Syrian Arab Republic Through Notes Verbales Dated 6, 16, and 20 November 2017, 28 December 2017, and 8 and 22 January 2018 (S/1596/2018, dated 2 March 2018).

43 For further information see: (a) Report on the work of the Declaration Assessment Team, EC-85/DG.25, dated 4 July 2017; (b) Outcome of Further Consultations with the Syrian Arab Republic Regarding its Chemical Weapons Declaration, EC-86/DG.30 dated 4 October 2017; and (c) Conclusions on the Outcome of Consultations with the Syrian Arab Republic Regarding its Chemical Weapons Declaration (EC-82/DG.18, dated 6 July 2016), www.opcw.org/fileadmin/OPCW/EC/82nd_EC/EC82dg18_c_.pdf.

44 Summary Update of the Activities Carried Out by the OPCW Fact-Finding Mission in Syria 2017 (S/1556/2017, dated 14 November 2017).

Mr Devroe discussed the OCW that were recently destroyed in Panama.[45] The Secretariat had to evaluate the suitability of different destruction options and ensure they were consistent with the obligations of the Convention (e.g. no environmental harm).[46] Explosive venting and hydrolysis were ultimately used.

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

(a) Even with small numbers of OCW, missions to dispose of them in non-routine environments (such as a jungle in Panama) can be resource intensive. For the Panama case, a team of 150 specialists was required.

(b) The Panama case demonstrates that OCW and ACW work can take place in environments and regions usually not associated with chemical weapons. This serves as a reminder that flexibility is required for the OPCW to perform non-routine work.

(c) The SAB recognises that the study—and disposal, when required— of OCW, ACW, and sea-dumped chemical weapons has produced the knowledge and methodologies needed to face the challenges of handling small numbers of items for disposal at the site of recovery. Scientific developments in this area should be monitored and inspector training might help facilitate engagement with experts.

Subitem 6(g): Rapid Response and Assistance Mission (RRAM)

6.18 Mr Mehran Rouzbahani (Head of the OPCW Inspectorate Capacity-Building and Contingency-Planning Cell) briefed the SAB on the OPCW Rapid Response and Assistance Mission (RRAM).[47] After reviewing its mandate and scope, the outcomes and lessons learned from table top and field exercises, including recent RRAM exercises in Romania and Serbia, were presented. Mr Rouzbahani concluded with a discussion of pertinent technical, logistical and procedural challenges, and how they were being addressed.

6.19 The RRAM is not a verification mission and thus is not constrained by the list of approved equipment. While this provides an opportunity to enhance field capabilities, the equipment would ideally also not be subject to dangerous goods transport restrictions and would be easily portable so that it can be carried on commercial flights. Such equipment includes handheld detectors, point-of-care test strips and devices, small unmanned aerial vehicles, and decontamination equipment. Computational tools such as dispersion modelling are also helpful to these missions.

45 (a) Panama: Concept Plan for the Destruction of Eight Old Chemical Weapons (EC-85/NAT.2, dated 16 June 2017), www.opcw.org/fileadmin/OPCW/EC/85/en/ec85nat02_e_.pdf; and (b) Initial Inspection of Old Chemical Weapons Declared by Panama as Abandoned and Located at San Jose Island (EC-28/S/3, dated 11 March 2002).

46 Chemical Weapons Convention Verification Annex, Part IV (A): Destruction of Chemical Weapons and Its Verification Pursuant to Article IV, Section C, www.opcw.org/chemical-weapons-convention/annexes/verification-annex/part-iva/.

47 (a) Establishment of a Rapid Response Assistance Team (S/1381/2016, dated 10 May 2016), www.opcw.org/fileadmin/OPCW/S_series/2016/en/s-1381-2016_e_.pdf; and (b) Guidelines for States Parties Requesting a Rapid Response and Assistance Mission (S/1429/2016, dated 17 October 2016), www.opcw.org/fileadmin/OPCW/S_series/2016/en/s-1429-2016_e_.pdf.

and Mr Rouzbahani updated the SAB on the capabilities the Secretariat is developing using these tools.

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

(a) The SAB could usefully provide advice on available tools and training that meet the transport and fieldable requirements of the RRAM. This could include innovative technologies recognised through the science review.

(b) The RRAM was established to assist States Parties, upon their request, in case of a chemical attack by terrorists. It can be viewed as a service provided by the OPCW with a legal basis in Article X of the Convention. States Parties can request this service, which could be to provide advice, and/or assist with the collection and analysis of samples (at the OPCW Laboratory or the designated laboratories) and/or facilitate capacity development with other agencies to provide the requesting State Party with capacities it may not otherwise have access to. The RRAM is not a challenge inspection (CI) or investigation of alleged use (IAU).

(c) As initial response is critical to incident management, it would be expected that the requesting State Party would have available initial information that could help guide the RRAM in preparing for deployment and for the kind of assistance it provides.

Subitem 6(h): Interagency Cooperation

6.21 Mr Ken Aoki (OPCW Office of Strategy and Policy) briefed the SAB on the background of the United Nations Counter-Terrorism Implementation Task Force (UNCTITF) Working Group on Preventing and Responding to WMD Attacks,[48] which is co-chaired by the OPCW and the International Atomic Energy Agency (IAEA), and an update of the Group's project to enhance the coordinated response of international organisations to attacks by terrorist groups using chemical and/or biological weapons. The Secretariat's efforts to better articulate interagency cooperation in the context of the RRAM were also highlighted. In particular, possible areas of interagency cooperation were identified by representatives of the World Health Organization (WHO) and INTERPOL as they observed the RRAM field exercise held in December 2017 in Romania. Mr Aoki noted that the Working Group is contemplating a project aimed at the prevention aspect of its remit, addressing the question: what could international organisations collectively do to help States Parties prevent the terrorist use of WMD materials?

6.22 Mr Aoki raised the question of whether there could be benefit to having interagency cooperation in the area of evolving science and technology, and what, in practical terms, this would mean (i.e., research programmes jointly sponsored by agencies, identification of research areas where many agencies would benefit, and/or greater interaction between science advisory mechanisms). It may be useful to consider areas

48 For further information see: www.opcw.org/special-sections/cttf-report/the-united-nations-counter-terrorism-implementation-task-force-cttf-and-the-working-group-on-preventing-and-responding-to-wmd-attacks/.

such as research, emergency management, vulnerability, and risk assessment to better define where interagency cooperation could be useful.

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

(a) A useful approach to finding interagency synergies could involve looking to other agencies with expertise as well as those with gaps. In this way, organisations can share expertise and avoid duplicating capabilities.

(b) The SAB has engaged on an ad hoc basis with other scientific advisory mechanisms. These interactions have been very useful and productive. However, it was noted that scientific boards within large organisations can also be isolated and difficult to access.

7. AGENDA ITEM SEVEN – Advice on chemicals

Subitem 7(a): Report from the Spiez Laboratory Schedule 1 Users Forum

7.1 Dr Christophe Curty briefed the SAB on the recent Schedule 1 Users Forum hosted by Switzerland in cooperation with the Secretariat from 22 to 25 January 2018 at the Spiez Laboratory.[49,50] This was the second time that this forum had been convened. The first workshop had taken place in Madrid in January 2014, hosted by the Government of Spain.[51] The Spiez workshop brought together practitioners from Schedule 1 facilities and provided them with a unique platform to share their experiences; 43 participants from 15 States Parties, along with members of the Secretariat, contributed to the workshop.

7.2 Schedule 1 facilities are permitted to produce, process, or consume Schedule 1 chemicals for purposes not prohibited by the Convention. These facilities must declare all their activities twice annually in accordance with the provisions of the Convention.[52] The work undertaken at the Schedule 1 facilities plays an important role in preventing the re-emergence of chemical weapons, through contributions to the development of improved protection, detection, and medical countermeasures against chemical warfare agents.

7.3 The workshop programme covered equipment, installations, materials, and safety and security and included an informative laboratory tour. Presentations and substantive discussions were also held on topics that included:

(a) the role, national objectives, and main activities of Schedule 1 facilities;

(b) infrastructure of Schedule 1 facilities;

(c) technical and operational measures for safe work;

49 OPCW news item www.opcw.org/news/article/opcw-schedule-1-users-forum-held-in-switzerland/.

50 For further information on Spiez Laboratory see: https://www.labor-spiez.ch/en/all/.

51 OPCW news item www.opcw.org/news/article/schedule-1-users-forum-held-in-spain/.

52 Status of Submission of Annual Declarations regarding Projected Activities and Anticipated Production in 2018 at Schedule 1 Facilities (S/1543/2017, dated 16 October 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1543-2017_e_.pdf.

(d) secure and safe storage of Schedule 1 chemicals;

(e) disposal of Schedule 1 chemicals and national regulations; and

(f) OPCW obligations, including annual declarations, inspections, and notifications.

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

(a) Workshops like the Schedule 1 Users Forum provide a unique venue to share knowledge and ensure that the required capabilities for working with Schedule 1 chemicals under the Convention are maintained. The SAB supports the continuation of the workshop series.

(b) Different Schedule 1 facilities have different safety approaches. The Schedule 1 Users Forum facilitates the sharing of best safety and security practices.

(c) Schedule 1 knowledge—in particular the synthesis and handling of Schedule 1 chemicals—will need to be maintained with adequate capability to support the OPCW mission.

Subitem 7(b): Shutting down a Schedule 1 facility

7.5 Dr Arjan Louter (OPCW Industry Verification Branch) and Mr Cheng Tang (SAB Vice-Chairperson) briefed the SAB on the process developed for the decommissioning of Schedule 1 facilities. They provided an introduction to the requirements for a Schedule 1 facility under the Convention and noted the absence of procedures for shutting a Schedule 1 facility. Under the Convention, a State Party can only operate one single small-scale facility (SSSF) and/or other facility for protective purposes (OFPP) for working with Schedule 1 chemicals at any given time. Therefore, it is important to understand any timelines for closing down an existing declared Schedule 1 facility and for the commissioning of a new facility, if applicable.

7.6 Mr Tang explained that China, based on discussions with the Secretariat, provided an "advanced notification" to the Secretariat to inform the latter about shutting down a declared SSSF as "planned changes" (in accordance with paragraph 14 of Part VI of the Verification Annex). The Secretariat confirmed receipt of the notification and conducted a final systematic inspection to the declared SSSF within 180 days of receipt of the notification. In this way, the declared SSSF was closed successfully. Mr Tang informed the audience that the Secretariat is considering issuing a note on guidance for the verification of cessation of activities at Schedule 1 facilities, and for verifying the commissioning of a new Schedule 1 facility following this type of closure.[56]

[56] Guidelines for Verification of Cessation of Activities at Closed Schedule 1 Facilities and for Verification of the Commissioning of New Schedule 1 Facilities Following Such Closure (S/1608/2018, dated 29 March 2018). www.opcw.org/fileadmin/OPCW/S_series/2018/en/s-1608-2018_e_.pdf.

Subitem 7(c): Modern concepts and tools for synthetic design

7.7 Professor Ahmed Saeed reviewed methods and approaches that are used to design synthesis routes for chemicals. Synthetic organic chemistry is the art of building up organic compounds from smaller entities, where synthesis of a complex organic compound requires suitable synthetic analysis and planning; this is accomplished using retrosynthetic analysis.[54] He explained that for chemical synthesis, there are ongoing needs for new methods to rapidly assemble highly pure molecules that possess an ever-increasing level of structural complexity. To make these methods scalable beyond the research laboratory, new processes are increasingly required to be environmentally friendlier, more efficient, and produce greater levels of structural variation in shorter reaction times. These demands are driving the development of novel technologies that are allowing the synthesis of new compounds at greater rates than previously thought possible.

7.8 Artificial intelligence (AI) aids the development of these methods and has brought value to synthetic design even when it is not used to its full extent. AI methods have been shown to enable chemists to overcome problems where conventional methods struggle. Professor Saeed introduced approaches that included molecular modelling and docking,[55] quantitative structure activity relationships (QSAR),[56] and computational and computer-assisted organic synthesis (CAOS).[57] His examples included nerve agents,[58] non-protein biological toxins,[59] and anti-cancer compounds.[59]

[54] Pattern recognition in retrosynthetic analysis: snapshots in total synthesis. R. M. Wilson, S. J. Danishefsky. *J. Org. Chem.*; 2007, *72(12)*, 4293-4305. DOI: 10.1021/jo070871s.

[55] Ab Initio Reactive Computer Aided Molecular Design. T. J. Martinez; *Acc. Chem. Res.*; 2017, *50(3)*, 652–656. DOI: 10.1021/acs.accounts.7b00010.

[56] (a) Current advances and new mindset in computer-aided drug design: A review. S. Pandey, B. K. Singh, *The Pharma Innovation Journal*, 2017, *6(8)*, 72-76. (b) The advancement of multidimensional QSAR for novel drug discovery - where are we headed? T. Wang, X.-S. Yuan, M.-B. Wu, J.-P. Lin, L. R.Yang; *Expert Opinion on Drug Discovery*, 2017, *12*, 769-784. DOI: 10.1080/17460441.2017.1336157.; and (c) Performance of deep and shallow neural networks, the universal approximation theorem, activity cliffs, and QSAR. D. A. Winkler, T. C. Le, *Molecular Informatics*, 2016, *36(1-2)*. DOI: 10.1002/minf.201600118.

[57] (a) Chematica: a story of computer code that started to think like a chemist. B. A. Grzybowski, S. Szymkuć, E. P. Gajewska, K. Molga, P. Dittwald, A. Wołos, T. Klucznik, *Chem.*; 2018, *4(3)*, 390-398. (b) Modelling chemical reasoning to predict and invent reactions. M.H.S. Segler, M. P. Waller, *ChemPlusChem Europe*, 2017, *23(25)*, 6118-6128. DOI: 10.1002/chem.201604556; and (c) Towards "AlphaChem": chemical synthesis planning with tree search and deep neural network policies. M. Segler, M. Preuß, M. P. Waller; available as a pre-print; 2017, arXiv: 1702.00020.

[58] Asymmetric biocatalysis of the nerve agent VX by human serum paraoxonase 1: molecular docking and reaction mechanism calculations. J. Sartorelli, A. A. de Castro, T. C. Ramalho, J. D. S. Giacoppo, D. T. Mancini, M. S. Caetano, E. F. F. Cunha; *Med. Chem. Res.*; 2016, *25(11)*, 2523-2533. DOI: 10.1007/s00044-016-1704-x.

[59] (a) Total synthesis of (−)- and (+)-decarbamoylsaxitoxin and (+)-saxitoxin. O. Isaac-Lam, K. Shinohara, K. Nagasawa, *Chem. Asian J.*; 2009, *4*, 277-285. DOI: 10.1002/asia.200800352. (b) A synthesis of (+)-saxitoxin. J. Fleming, J. Du Bois, *J. Am. Chem. Soc.*; 2006, *128(12)*, 3926–3927. DOI: 10.1021/ja0608545; (c) An efficient total synthesis of optically active tetrodotoxin. T. Nishikawa, D. Urabe, M. Isobe, *Angew. Chem. Int. Ed.*; 2004, *43*, 4782-4785. Doi:10.1002/anie.200460295; and (d) A Stereoselective Synthesis of (−)-Tetrodotoxin. A. Hinman, J. Du Bois, *J. Am. Chem. Soc.*; 2003, *125(38)*, 11510–11511. DOI: 10.1021/ja0368305; and (e) Total synthesis of (+)-saxitoxin. P. A. Jacobi, M.J. Martinelli, S. Polanc, *J. Am. Chem. Soc.*; 1984, *106(19)*, 5594-5595. DOI: 10.1021/ja00331a052.

Professor Saeed concluded with a look at recent results comparing the capabilities of CAOS programmes to retrosynthetic analysis carried out in the absence of computational methods.[61]

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

(a) Concerns have been raised about the use of AI systems to allow the design of synthesis routes to toxic chemicals from accessible precursors in order to avoid having to procure highly regulated materials. However, these types of AI tools are not currently integrated with the capabilities for designing experimental procedures, thus requiring chemistry knowledge, skills, equipment, and materials available to take forward the results of an AI-planned synthesis.

(b) In future, it may be possible that AI tools will be capable of providing for both synthesis route design and experimental procedures. This would be a desirable output for AI tools that are used to synthesise molecules using fully automated equipment. Such systems could also be built with security features that do not allow them to design molecules containing specific structural features (Schedule 1 chemicals and their precursors for example).

8. AGENDA ITEM EIGHT – Developments in science and technology

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

8.1 Dr Jonathan Forman provided a perspective on science monitoring, its value, and what it can and cannot achieve for informing how a changing scientific landscape impacts the Convention. He discussed how millions of scientific publications[62] and patents[63] are published each year across a highly multidisciplinary[64] scientific landscape, and provided examples involving Schedule 1 chemicals, noting that since the entry into force of the Convention, the number of scientific journal publications and patents with mention of any Schedule 1 chemical in them has actually increased yearly in volume, with the majority focussed on toxicology, biochemistry, and

60 (a) Computer- aided design of anticancer 1,4- naphthoquinone derivatives. L. H. M. Ali, A. E. M. Saeed; *Chem. Sc. Inter. J.*; 2017, *18(4)*, 1-11. DOI: 10.9734/CSIJ/2017/31344; and (b) Synthesis of some 2-aryl- and 2,3-diarylquinolin-4-carboxylic acid derivatives. A. E. M. Saeed, S. A. Elhadi; *Synthetic Communications*. 2010, *41(10)*, 1435-1443. DOI: 10.1080/00397911.2010.486508.

61 (a) Chemists test computer-planned syntheses for the first time. S. Lemonick; *Chemical & Engineering News*. 2018, *96(10)*, 1-3; and (b) Efficient syntheses of diverse, medicinally relevant targets planned by computer and executed in the laboratory. T. Klucznik, B. Mikulak-Klucznik, M. P. McCormack, H. Lima, S. Szymkuc, M. Bhowmick, K. Molga, Y. Zhou, L. Rickershauser, E. P. Gajewska, A. Toutchkine, P. Dittwald, M. P. Startek, G. J. Kirkovits, R. Roszak, A. Adamski, B. Sieredzinska, M. Mrksich, S. L. J. Trice, B. A. Grzybowski; *Chem*; 2018, *4(3)*, 522-532. DOI: 10.1016/j.chempr.2018.02.002.

62 The STM Report An overview of scientific and scholarly journal publishing. M. Ware, M. Mabe; International Association of Scientific, Technical and Medical Publishers: The Hague, 2015, https://www.stm-assoc.org/2015_02_20_STM_Report_2015.pdf.

63 World Intellectual Property Indicators - 2016; Economics & Statistics Series. WIPO; 2016; ISBN: 978-92-805-2805-3, http://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2016.pdf.

64 Visualization of disciplinary profiles: enhanced science overlay maps. S. Carley, A. L. Porter, I. Rafols, L. Leydesdorff; *J. Data Info. Science*. 2017, *2(3)*, 68-111. DOI: 10.1515/jdis-2017-0015.

pharmacology. Dr Forman then presented a number of findings from the Secretariat's watching brief on scientific developments relevant to the report of the SAB to the Fourth Review Conference. This overview included metal organic frameworks for chemical warfare agent destruction,[65] microbes that metabolise chemical agent hydrolysis products,[66] patents on synthetic biology for fine chemical production[67] (noting that the increasing number of patents does not necessarily reflect the actual processes used in manufacturing across the fine chemical sector),[68] recent reports of chemical weapon agent synthesis route attribution,[69] the use of data analysis to recognise unusual biochemical changes,[70] low cost point-of-care devices for pathogen detection,[71] omics tools and methodologies for toxicology applications,[72] mechanisms

65 Metal–organic frameworks for the removal of toxic industrial chemicals and chemical warfare agents. N. S. Bobbitt, M. L. Mendonca, A. J. Howarth, T. Islamoglu, J. T. Hupp, O. K. Farha, R. Q. Snurr; *Chem. Soc. Rev.*; 2017, *46(11)*, 3357-3385. DOI: 10.1039/C7CS00108H.

66 (a) Full-scale demonstration of biological processing of mustard hydrolysate surrogate in ICBs at the Pueblo chemical agent-destruction pilot plant. P. J. Usinowicsz, J. Earley, Y. Nurdogan, C. Oclassen; Proceedings of the Water Environment Federation. 2017, WEFTEC 2017 (Session 601-620), 5203-5213. DOI: 10.2175/193864717822156965; (b) microbial responses to mustard gas dumped in the Baltic Sea; N. Medvedeva, Y. Polyak, H. Kankaanpaa, T. Zaytseva; Marine Environmental Research. 2009, *68(2)*,71-81. DOI: 10.1016/j.marenvres.2009.04.007; and (c) Engineering bacteria to catabolize the carbonaceous component of sarin: teaching E. coli to eat isopropanol. M. E. Brown, A. Mukhopadhyay, J. D. Keasling; *ACS Synthetic* Biology; 2016, *5(12)*, 1485-1496. DOI: 10.1021/acssynbio.6b00115.

67 Mapping the patent landscape of synthetic biology for fine chemical production pathways. P. Carbonell, A. Gök, P. Shapira, J. Faulon; *Microbial Biotechnology*; 2016, *9(5)*, 687–695. DOI: 10.1111/1751-7915.12401.

68 See paragraphs 9.2 and 9.3 of SAB-26/WP.2 (dated 19 October 2017), cited in footnote 7(4) of this report.

69 (a) Part 1: Tracing Russian VX to its synthetic routes by multivariate statistics of chemical attribution signatures. K. H. Holmgren, C. A. Valdez, R. Magnusson, A. K. Vu, S. Lindberg, A. M. Williams, A. Alcaraz, C. Ástot, S. Hok, R. Norlin; *Talanta*; 2018.DOI: 10.1016/j.talanta.2018.02.104; (b) Part 2: Forensic attribution profiling of Russian VX in food using liquid chromatography-Mass Spectrometry. D. Jansson, S. W. Lindström, R. Norlin, S. Hok, C. A. Valdez, A. M. Williams, A. Alcaraz, C. Nilsson, C. Ástot; *Talanta*; 2018. DOI: 10.1016/j.talanta.2018.02.103; (c) Part 3: Solid phase extraction of Russian Vx and its chemical attribution signatures in food matrices and their detection by GC-MS and LC-MS. A. M. Williams, A. K. Vu, B. P. Mayer, S. Hok, C. A. Valdez, A. Alcaraz; *Talanta*. 2018. DOI 10.1016/j.talanta.2018.03.044; (d) Synthesis route attribution of sulfur mustard by multivariate data analysis of chemical signatures. K. H. Holmgren, S. Hok, R. Magnusson, A. Larsson, C. Ástot, C. Koester, D. Mew, A. K. Vu, A. Alcaraz, A. M. Williams, R. Norlin, D. Wiktelius; *Talanta*. 2018. DOI: 10.1016/j.talanta.2018.02.100; and (e) On the use of spectra from portable raman and ATR-IR instruments in synthesis route attribution of a chemical warfare agent by multivariate modelling. D. Wiktelius, L. Ahlinder, A. Larsson, K. H. Holmgren, R. Norlin, P. O. Andersson; *Talanta*. 2018. DOI: 10.1016/j.talanta.2018.02.108.

70 See also SAB-26/WP.1 (dated 21 July 2017), cited in footnote 7(3) of this report.

71 Infectious pathogens meet point-of-care diagnostics. M. Zarei; *Biosensors and Bioelectronics*; 2018, *106*, 193-203. DOI: 10.1016/j.bios.2018.02.007.

72 (a) Systems toxicology: real world applications and opportunities. T. Hartung, R. E. FitzGerald, P. Jennings, G. R. Mirams, M. C. Peitsch, A. Rostami-Hodjegan, I. Shah, M. F. Wilks, S. J. Sturla; *Chem. Res. Toxicol.*; 2017, *30(4)*, 870-882. DOI: 10.1021/acs.chemrestox.7b00003; (b) Integrating ion mobility spectrometry into mass spectrometry-based exposome measurements: what can it add and how far can it go? T. O. Metz, E. S. Baker, E. L. Schymanski, R. S. Renslow, D. G. Thomas, T. J. Causon, I. K. Webb, S. Hann, R. D. Smith, J. G. Teeguarden; *Bioanalysis*; 2017, *9(1)*, 81-98. DOI: 10.4155/bio-2016-0244; and (c) Bioregulatory systems medicine: an innovative approach to integrating the science of molecular networks, inflammation, and systems biology with the patient's autoregulatory capacity? A. W. Goldman, Y. Burmeister, K. Cesnulevicius, M. Herbert, M. Kane, D. Lescheid, T.

of lung damage from chlorine exposure,[73] preliminary work on understanding genomic differences that might impact nerve agent effects,[74] and examples of the use of clinical diagnosis from video footage of chemical exposure casualties.[75] Dr Forman also discussed the uncertainties of science monitoring, including reproducibility[76] and the indeterminate number of chemical structures that might have drug-like properties.[77]

8.2 Dr Forman discussed the value of tools and technologies that can collect and analyse data in real time, which may be able to recognise a sudden or unexpected chemical event. This could be remote sensing technologies for sensing observable features in vegetation. Referring to the SAB's workshop on emerging technologies, Dr Forman emphasised a need to test innovative technologies in field conditions under which they might find use. He discussed how scientific monitoring can provide great insights into new developments and trends, but understanding the impacts thereof requires active engagement with both scientific communities and the stakeholders who might be end-users of the new developments. Additionally, he noted that predicting long-term impact will always involve uncertainty.

Subitem 8(b): A transatlantic perspective on 20 emerging issues in biological engineering

8.3 Dr Bonnie C. Wintle and Dr Christian R. Boehm (guest speakers from the Centre for the Study of Existential Risk, University of Cambridge, United Kingdom of Great Britain and Northern Ireland) presented the results of a horizon scanning project they had recently completed. Horizon scanning is a systematic way to efficiently examine what can be an overwhelming volume of information, looking for signals that give an early indication of poorly recognised threats and opportunities. Drawing on large groups of people from different disciplines to scan, verify, and analyse information broadens the scope of issues typically considered by policy- and decision-makers. Their presentation began with an introduction to horizon scanning approaches, with a focus on iterative Delphi-style methodology.[78] They concluded with a discussion of the main findings of a scan that used the method to explore emerging issues for global

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McCaffrey, M. Schultz, B. Seelhemer, A. Smit, G. St. Laurent III,B. Berman; *Front. Physiol.*, 2015, 6, 225. DOI: 10.3389/fphys.2015.00225.

Mechanisms and modification of chlorine-induced lung injury in animals,A. K. Yadav, A. Bracher, S. F. Doran, M. Leustik, G. L. Squadrito, E. M. Postlethwait, S. Matalon. *Proc. Am. Thorac. Soc.*; 2010, *7(4)*, 278–283. DOI: 10.1513/pats.201001-009SM.

The role of genetic background in susceptibility to chemical warfare nerve agents across rodent and non-human primate models. L. M. Matson, H. S. McCarren, C. L. Cadieux, D. M. Cerasoli J. H. McDonough; *Toxicology*; 2018, *393*, 51-61. DOI: 10.1016/j.tox.2017.11.003.

A comparative toxidrome analysis of human organophosphate and nerve agent poisonings using social media. *Clinical and Translational Science*, 2017, *10(3)*, 225-230. DOI:10.1111/cts.12435.

1500 Scientists lift the lid on reproducibility; M. Baker, *Nature*, 2016, *533*, 452-454. DOI: 10.1038/533452a.

The drug-maker's guide to the galaxy. A. Mullard; *Nature*, 2017, *549*, 445–447. DOI: 10.1038/549445.

Methods for collaboratively identifying research priorities and emerging issues in science and policy. W. J. Sutherland, E. Fleishman, M. B. Mascia, J. Pretty, M. A. Rudd; *Methods in Ecol. and Evol.*; 2011, *2*, 238-247. DOI: 10.1111/j.2041-210X.2010.00083.x.

society accompanying advances in biological engineering.[79] The findings identified trends that included a shift of biology towards an information science, the democratisation of technology, and the infrastructure of the future bioeconomy.

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

(a) Cyber security and cyber espionage are set to pose significant challenges for biology as this scientific discipline shifts towards an information science involving more computational equipment, as such equipment (e.g. a DNA synthesiser) could potentially be hacked in the future.

(b) The study included participants located primarily in North America and Western Europe, and it was acknowledged that if participants represented a different regional makeup, the outcomes would vary.[80]

(c) While the study focussed on biotechnology, a number of overlapping issues in the chemical sciences were noted. In particular, the potential for biotechnology to enable decentralised chemical production.

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

Subitem 9(a): Dissemination of toxic chemicals – Can biosensors serve as detectors?

9.1 Dr Franz Worek (guest speaker, Deputy Director of the Bundeswehr Institute of Pharmacology and Toxicology, Munich, Germany) presented findings from research on the use of sentinel species for the detection of chemical warfare agents. He noted that recent use of chemical warfare agents combined with increased interest by terrorist groups in toxic chemicals[81] presents a continuing threat to our societies and that early warning and detection is a key component for effective countermeasures against such deadly chemicals. Presently available detection systems have a number of major drawbacks, including a lack of automated, remote warning, detection of primarily low-volatility chemicals, and a limited spectrum. In addition, the availability of detectors may be limited and insufficient. An alternative approach

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A Transatlantic perspective on 20 emerging issues in biological engineering. B. C. Wintle, C. R. Boehm, C. Rhodes, J. C. Molloy, P. Millett, L. Adam, R. Breuling, R. Carlson, R. Casagrande, M. Dando, R. Doubleday, E. Drexler, B. Edwards, T. Ellis, N. G. Evans, R. Hammond, J. Haseloff, L. Kahl, T. Kuiken, B. R. Lichman, C. A. Matthewman, J. A. Napier, S. S. ÓhÉigeartaigh, N. J. Patron, E. Perello, P. Shapira, J. Tait, E. Takano, W. J. Sutherland. *eLife*. 2017. 6. e30247. DOI 10.7554/eLife.30247.

For comparison to the 2017 study, a Delphi study on synthetic biology was conducted in India in 2012 Exploring the Future of Synthetic Biology in India and its probable pathways from infancy to maturity. D. Singh, P. K. Dhar; *Curr. Synthetic Sys. Biol.*; 2013, 1(1), 106. DOI: 10.4172/2332-0737.1000106

Toxicology of organophosphorus compounds in view of an increasing terrorist threat. F. Worek, T. Wille, M. Koller, H. Thiermann. *Arch. Toxicol. 2016, 90(9)*, 2131–2145. DOI: 10.1007/s00204-016-1772-1.

could be the use of biosensors, in the form of certain animal species,[82] as sentinels for providing early warning of the presence of toxic chemicals.

9.2 Important requirements for the successful application of biosensors are:

(a) coverage of a broad spectrum of toxic chemicals (e.g. to recognise a meaningful change);

(b) a rapid and specific physiological, behavioural, or (bio)chemical response;

(c) sensitivity, at least that of humans; and

(d) low cost, easy to handle, and readily available.

9.3 In the past, different animal species have been used effectively as sentinels of environmental toxicants. A well-known approach is the use of canary birds in coal mines, which can be considered an example for translation to situations where available detectors do not work sufficiently. This species proved to be sensitive to nerve agents, but the use as biosensors is hampered by two facts: canary birds are popular pets and included in animal legislation. Insects could serve as an alternative: cockroaches were tested as a potential biosensor.[83] It turned out that cockroaches were sensitive to nerve agents, blood agents, and blistering agents, and showed clearly visible reactions. They could potentially be used in field camps or residential areas. However, cockroaches will not provide information on the class of chemical agents used and thus can only be classified as a warning system.

9.4 Another approach was developed to disclose contamination of skin by organophosphorus compounds and carbamates by a colorimetric assay based on reaction with human acetylcholinesterase.[84] A rapid, generic, and ready-to-use skin disclosure kit proved to be extremely sensitive, detecting nerve agent concentrations several orders of magnitude below the incapacitating dose.

9.5 Similar to chemical detectors, biosensors must be available at the site of a toxic chemical attack. In the event of unavailable detection capabilities, dissemination of chemical warfare agents affects "natural" biosensors, including wild, farm, or domestic animals. In this regard, biosensors can be valuable tools for detection and may serve as a trigger-to-react in the event of the dissemination of toxic chemicals.

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82 Animals as sentinels of human health hazards of environmental chemicals. W. H. van der Schalie, H.S. Gardner Jr., J. A. Bantle, C.T. De Rosa, R. A. Finch, J. S. Reif, R. H. Reuter, L. C. Backer, J. Burger, L. C. Folmar, W. S. Stokes; *Environ. Health Perspect.*: 1999,*107(4)*, 309–315.

83 (a) Immediate responses of the cockroach *Blaptica dubia* after the exposure to sulfur mustard. T. Popp, R. Lüling, I. Boekhoff, T. Seeger, F. Branoner, T. Gudermann, H. Thiermann, F. Worek, D. Steinritz. *Arch. Toxicol.*; 2018, 92(1), 337-346. DOI: 10.1007/s00204-017-2064-0. (b) *Blaptica dubia* as sentinels for exposure to chemical warfare agents – a pilot study. F. Worek, T. Seeger, K. Neumaier, T. Wille, H. Thiermann.*Toxicol. Lett.*; 2016, 262, 12–16. DOI: 10.1016/j.toxlet.2016.09.006.

84 Development of a sensitive, generic and easy to use organophosphate skin disclosure kit. F. Worek, A. Wosar, M. Baumann, H. Thiermann, T. Wille; Toxicol. Lett.: 2017, *280*, 190–194. DOI: 10.1016/j.toxlet.2017.08.021.

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

(a) Systems that give simple read-outs, can be deployed in resource-limited settings, and that do not require operation by trained experts are highly valuable. These tools do not replace the need for more robust off-site analysis for confirmation of the identity of the toxic chemical, but they do serve as a valuable warning system and can aid decision making in the field.

(b) Non-flying insect biosensors may be well suited for recognising the possible presence of involatile and persistent agents that can be difficult to detect with some handheld detectors.

(c) Insect-based biosensors may be useful in safety monitoring, where slow and prolonged exposure to a toxic material may be occurring.

Subitem 9(b): "If Plants Could Talk": an artificial intelligence application

9.7 Mr Mukremin Balci (OPCW Inspectorate Safety and Analytical Chemistry Cell) briefed the SAB on potential AI applications for chemical warfare agent identification based on image recognition and categorisation. He described how machine learning might be applied to image-based classification of the effects of chemical warfare agents on vegetation.[85,86,87] Mr Balci presented results from the image-based classification of leaf diseases[88] as proof-of-concept and described how such a project might be taken forward. A data set of images of plants that have been exposed to specific chemical warfare agents is needed to develop a useful AI tool.

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85 Examples of chlorine gas exposure to vegetation: (a) Development of a vegetation-damage indicator as a means of post-accident investigation for chlorine releases. R. F. Griffiths, L. E. Smiths; *J. Hazardous Materials*: 1990, *23(2)*, 137-165. DOI: 10.1016/0304-3894(90)85025-X. (b) Injury by sulfur dioxide, hydrogen fluoride, and chlorine as observed and reflected on vegetation in the field. I. J. Hindawi; *J. of the Air Pollution Control Assn.*: 1968, *18(5)*, 307-312. DOI: 10.1080/00022470.1968.10469130.

86 Examples of VX exposure to vegetation: Visual characterization of VX droplets on plant foliage. M. Simini, R. T. Checkai, M. V. Haley, *Edgewood Chemical Biological Centre*; U.S. Army Research, Development and Engineering Command; 2016, ECBC-TR-1393, http://www.dtic.mil/dtic/tr/fulltext/u2/1012054.pdf. (b) Persistence and effective half-life of chemical warfare agent VX on grass foliage. R. T. Checkai, M. V. Haley, M. Simini, R. J. Lawrence, R. G. Kuperman, W. T. Muse, R. A. Evans, M.W. Busch. *Edgewood Chemical Biological Centre*; U.S. Army Research, Development and Engineering Command; 2017, ECBC-TR-1469, http://www.dtic.mil/dtic/tr/fulltext/u2/1038552.pdf. (c) Critical parameters for predictive modeling of chemical agent persistence on the battlefield: the effective half-life of VX on plant foliage. R. T. Checkai, M. V. Haley, M. Simini, R. G. Kuperman. *Edgewood Chemical Biological Centre*; U.S. Army Research, Development and Engineering Command, https://www.ecbc.army.mil/about/posters/2015_C19.pdf (poster).

87 An example of mustard agent simulant exposure to vegetation: Quenching Action of Monofunctional Sulfur Mustard on Chlorophyll Fluorescence: Towards an Ultrasensitive Biosensor. S. Kaur, M. Singh, S. J. S. Flora; *Appl. Biochem. Biotechnol.*: 2013, *171*, 1405–1415. DOI 10.1007/s12010-013-0429-2.

88 The study was conducted using images of plant leaves obtained from Plant Village, https://plantvillage.org/. The use of this data set to use image recognition to diagnose plant diseases has been previously reported: Using deep learning for image-based plant disease detection. S. P. Mohanty, D. P. Hughes, M. Salathé; *Front. Plant Sci.*: 2016, *7*, 1419. DOI: 10.3389/fpls.2016.01419.

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

(a) Laboratories that have data (high quality and well documented images) of chemical warfare agent effects on plant leaves could consider collaborating on the development of an image database. Several SAB members expressed interest.

(b) The availability of data from agricultural chemical tests for regulatory compliance could be useful in generating the required dataset. This kind might include data gathered from the use of organophosphorus and organochlorine pesticides on plants.

Subitem 9(c): Update from the OPCW Laboratory

9.9 Mr Stuart Thomson (OPCW Laboratory) updated the SAB on the biotoxin exercise that he had described to the Board at its Twenty-Sixth Session.[89] The laboratories were given details of a fictional scenario in which aqueous and white powder samples that had tested positive for ricin were provided. The laboratories were told that *Ricinus communis* and *Abrus precatorius* seeds and several deceased small animals were also discovered at the site where the samples where obtained. The laboratories were only required to detect and report on ricin. A total of 21 laboratories participated. Reports have been received and are under evaluation. Mr Thomson discussed the preliminary results, noting that some laboratories did not meet the requirements for unambiguous detection, and specifying the various methods each laboratory had used. These included enzyme linked immunosorbent assay (ELISA), lateral flow assay, SDS-Page, LC-MS/MS,[90] and LC-MS/HRMS.[91]

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

(a) Future exercises on toxins could usefully include toxins beyond the two listed in Schedule 1 (ricin and saxitoxin). Interest from participating laboratories is mixed, as some prefer to stay within the Schedules of the Convention for training exercises.

(b) These exercises have been helpful in evaluating potential laboratories that could be called upon if there were a need to have an independent laboratory analysis of a sample containing a toxin.

Subitem 9(d): Host-based early warning of biological agent exposure

9.11 Dr Albert Swiston (guest speaker, Massachusetts Institute of Technology, Lincoln Laboratory, United States of America) presented his work on finding methods for the early warning of biological agent exposure. Early pathogen exposure detection allows better patient care and faster implementation of public health measures (patient isolation and contact tracing, for example). Existing exposure detection most frequently relies on overt clinical symptoms, namely fever, during the infectious prodromal period. Dr Swiston has been working toward the development of a robust

89 See paragraph 9.6 of SAB-26/1(dated 20 October 2017), cited in footnote 7(5) of this report.

90 LC-MS/MS: Liquid chromatography-Mass Spectrometry/Mass Spectrometry.

91 LC-MS/HRMS: Liquid chromatography-Mass Spectrometry/High Resolution Mass Spectrometry.

machine learning-based method to better detect asymptomatic states during the incubation period using subtle, sub-clinical physiological markers.[92,93] For most of the subjects in Dr Swiston's studies, detection is achieved well before the onset of fever. Studies of cross-validation across exposure (various viruses, exposure routes, animal species, and target dose) indicated a 51-hour mean early detection (at 0.93 area under the receiver-operating characteristic curve (AUCROC)). Evaluations of the algorithm against entirely independent datasets for Lassa, Nipah, and Y. pestis exposures unused in algorithm training and development yielded a mean 51-hour early warning time (at AUCROC = 0.95). Dr Swiston highlighted the most informative physiological indicators for early detection and options for extending this capability to limited datasets such as those available from wearable, non-invasive, ECG-based sensors.

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

(a) As specific diagnostic tests may not always be available for unexpected or emerging diseases and pathogens, generic indicators of a meaningful and negative change in health status can have significant value in identifying a need for treatment and/or quarantine.

(b) To help in the removal of confounding effects, data for a given individual can be measured during sleeping hours. This is when the activity and stress levels observed over the course of a day for a given individual would not interfere with recognising infection-relevant signal changes. Data collected over a set time period while sleeping on a daily basis should be sufficient for early warning purposes.

(c) Practical ways to handle large amounts of data are also important aspects of collecting physiological indicators. Dr Swiston noted that for each 30-minute window of data collection, it was possible to take a random *n* minute interval for the value to use for analysis (where *n* might be in the range of 1-5).

(d) There can be huge variability in the mechanisms of viral and bacterial infection. However, in the initial phases, body responses to infection by viruses or bacteria appear to have similarities, which is consistent with the production in the body of a similar set of inflammatory markers (cytokines, chemokines, and prostaglandins). As infection progresses, the marker changes would become more specific, and a generic indicator might be less discriminatory between a viral or bacterial infection.

92 Detecting pathogen exposure during the non-symptomatic incubation period using physiological data: L. Milechin, S. Davis, T. Patel, M. Hernandez, G. Ciccarelli, S. Schwartz, S. Samsi, E. Hensley, A. Goff, J. Tietjy, S. Johnston, B. Parcell, C. Cabrera, J. Fleischman, A. Reuther, F. Rossi, A. Honko, W. Pratt, A. Swiston Jr.; *bioRxiv*; 218818; DOI: 10.1101/218818

93 Dr Swiston's work is supported under United States Air Force Contract No. FA8721-05-C-0002 and/or FA8702-15-D-0001. Any opinions, findings, conclusions or recommendations expressed the summaries of Dr Swiston's presentation to the SAB are those of Dr Swiston and do not necessarily reflect the views of the United States Air Force.

(e) The SAB had previously recognised potential for the use of wearable non-invasive monitoring tools to recognise signs and symptoms of chemical exposure.[94] Dr Swiston's presentation has served to reinforce this view.

10. AGENDA ITEM TEN – Chemical forensics and investigative technologies

Subitem 10(a): First meeting and report of the temporary working group on investigative science and technology

10.1 Dr Veronica Borrett (Chairperson of the SAB's TWG on investigative science and technology) briefed the SAB on the first meeting of the TWG, which was held at the OPCW from 12 to 14 February 2018.[95] 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, or location) of evidence, and the integration of multiple and diverse inputs to reconstruct a past event.[96]

10.2 The first meeting provided an opportunity to engage with the Secretariat, particularly with individuals experienced in contingency operations, in order to highlight the operational capabilities, requirements and challenges for inspectors, as well as the OPCW Laboratory and designated laboratories. Forensic experts shared their experience in investigative and laboratory practices suitable for jurisdictional legal environments, with the aim of highlighting forensic capabilities and potential resources that are important for the review of relevant methods and capabilities.

10.3 Six sub-groups were formed, each with a lead point of contact. These were: (1) Forensic Methods and Capabilities, (2) Data Collection and Management, (3) Sampling, Detection and Analysis, (4) Integrity of Scene and Evidence Collection, (5) Provenance, and (6) Additional Considerations, which will focus on any additional advice on Secretariat proposals for methodologies, procedures, technologies, and equipment for investigative purposes. In break-out sessions these sub-groups identified areas of focus and priority. The sub-groups will work on these proposals intersessionally and report back to the TWG to further shape the way forward. The second meeting of the TWG will be held from 14 – 16 November 2018.

10.4 In the discussion that followed, it was noted that forensic toxicology is an area in which training and access to information could be of benefit to States Parties. The findings of the TWG, particularly where connections can be made to experts in this field, is valuable.

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94 See paragraphs 9.4 – 9.6 and 10.2 – 10.5 of SAB-26/WP.1 (dated 21 July 2017), cited in footnote 7(3) of this report.

95 Summary of the First Meeting of the Scientific Advisory Board's Temporary Working Group on Investigative Science and Technology (SAB-27/WP.1, dated 26 February 2018), www.opcw.org/fileadmin/OPCW/SAB/en/sab-27-wp01_e_.pdf.

96 The terms of reference (TOR) were first published in Annex 2 of SAB-25/1* (dated 31 March 2017), cited in footnote 7(2) of this report. A quick reference guide to the questions of the TOR can be downloaded from the OPCW public website. www.opcw.org/fileadmin/OPCW/SAB/en/TWG_Investigative_Science_Tech_Questions.pdf.

Subitem 10(b): Investigation of a chemical agent incident

10.5 Dr Yasuo Seto gave a presentation on investigations into the sarin attacks that occurred in Japan in the 1990s, including his involvement as an investigator. He began with a historical look at the acts of chemical terrorism that had been carried out by the Aum Shinrikyo Cult,[97] then discussed technical details of the forensic analysis (including sampling and analysis) undertaken in response to the Matsumoto and Tokyo subway sarin attacks in 1994 and 1995.[98] Dr Seto described forensic work related to the sarin attacks, including an investigation of a suspected sarin manufacturing facility.[99] He concluded with an overview of research and development performed by the National Research Institute of Police Science[100] on analytical methods for chemical warfare agents,[101] on-site countermeasure technologies,[102] and decontamination.[103]

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

(a) This presentation of the first-hand experience of an investigation into an act of chemical terrorism on a civilian population and its aftermath was highly informative. The perspectives provided complement the experience of the Secretariat's contingency operations for non-routine operating environments, which present their own challenges and constraints.

(b) A number of environmental signatures in vegetation were noted in the presentation, including a tree with discoloured leaves resulting from exposure

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97 317. 1999. ACS Symposium Series. Vol. 745. ISBN: 9780841236301. eISBN: 9780841217508. DOI: 10.1021/bk-2000-0745.ch020.

98 (a) The White Paper on Police. 1995; National Police Agency; Government of Japan; Tokyo, Japan; (b) The White Paper on Police. 1996; National Police Agency; Government of Japan; Tokyo, Japan; and (c) Toxicological analysis of victim's blood and crime scene evidence samples in the sarin gas attack caused by the Aum Shinrikyo Cult. Y. Seto, N. Tsunoda, M. Kataoka, K. Tsuge and T. Nagano; Natural and Selected Synthetic Toxins Biological Implications. 1999. ch. 21, 318-332; eds. A. A. Tu and W. Gaffield; American Chemical Society. ISBN: 9780841236301.

99 (a) Sarin gas attacks in Japan and forensic investigations - a case report. Y. Seto, *Science, Technology, and National Security*; 2002, 74−88; eds. S. K. Majumdar, L. M. Rosenfeld, E. W. Miller, M. F. Rieders, S. S. Alexander, A. I. Panah; Pennsylvania Academy of Science, Easton, PA. ISBN: 0945809182; (b) The sarin gas attacks in Japan and the related forensic investigation. Y. seto; *Treaty enforcement and international cooperation in criminal matters*, 2002, 301-307, eds. R. Yepes-Enriquez, L. Tabassi; T. M. C. Asser Press; The Hague. ISBN: 978-90-6704-150-8; and (c) The sarin gas attack in Japan and the related forensic investigation. Y. Seto; *Synthesis*; 2001, Summer, 14−17.

100 For further information on the National Research Institute for Police Science, see: http://www.npa.go.jp/nrips/en/index.html.

101 On-site detection of chemical warfare agents. Y. Seto; *Handbook of the Toxicology of Chemical Warfare Agents*; 2015, ch. 60, 897-914, 2nd ed., ed. by R. C. Gupta; Elsevier; Amsterdam. ISBN: 978-0-12-374484-5.

102 On-site detection as a countermeasure to chemical warfare/terrorism. Y. Seto; *Forensic Sci. Rev.*; 2014, 26, 23-51.

103 Research and development of on-site decontamination system for biological and chemical warfare agents. Y. Seto; *J. Health Sciences*; 2011, 57(4), 311-333. DOI: 10.1248&jhs.57.311.

to hydrofluoric acid released into the environment during the sarin production process by Aum Shinrikyo members.

11. AGENDA ITEM ELEVEN – Future work of the Scientific Advisory Board

Subitem 11(a): The road to the Fourth Review Conference

11.1 Mr Szymon Bocheński (OPCW Office of Strategy and Policy) briefed the SAB on the work of the Open-Ended Working Group for the Preparation for the Fourth Review Conference (OEWG-RC), which had been established by the Conference at its Twenty-Second Session. The Conference also established the Bureau of the OEWG-RC, which is composed of the Chairperson, H.E. Mr I Gusti Agung Wesaka Puja of Indonesia, and four Vice-Chairpersons representing each of the regional groups: H.E. Mrs Odette Melono of Cameroon, African Group; H.E. Mr Marcin Czepelak of Poland, Eastern European Group; H.E. Mr Agustin Vásquez Gómez of El Salvador, GRULAC;[104] and H.E. Mr Kenneth D. Ward of the United States of America, WEOG.[105] The Working Group has initiated its preparations and has held four meetings prior to the Twenty-Seventh Session of the SAB.

(a) The first meeting took place on 25 January 2018. The Director-General delivered opening remarks, and States Parties presented their expectations for the preparatory process. The meeting provided an opportunity to discuss matters of an organisational nature focussing on a programme of work and a document on related organisational aspects of the Working Group.

(b) The second meeting, on 6 February 2018, was devoted to the topic of general obligations of States Parties, in particular the destruction and elimination of chemical weapons and related facilities (including old and abandoned chemical weapons), as well as activities not prohibited by the Convention, under which the issue of declarations was discussed.

(c) On 21 February 2018, the OEWG-RC held its third meeting, which focussed on industry verification with special emphasis on risk assessment and selection of facilities to be inspected, sampling and analysis, new technologies to augment the OPCW's verification capabilities, and other chemical production facilities (OCPF), including general provisions and risks.

(d) The last meeting of the OEWG-RC before the Twenty-Seventh Session of the SAB took place on 7 March 2018. It concentrated on Article IX of the Convention, in particular on consultations, cooperation, and fact-finding, challenge inspections, as well as and investigations of alleged use and other verification-related issues.

11.2 Mr Bocheński informed the SAB that the OEWG-RC will hold a dedicated meeting on developments in science and technology on 6 June 2018. A representative of the SAB is invited to provide a briefing on the main findings and recommendations from

[104] GRULAC: Group of Latin America and Caribbean Countries.

[105] WEOG: Western European and Others Group.

the SAB's report on developments in science and technology for the Fourth Review Conference.

11.3 Mr Bocheński concluded with an update on the Open-Ended Working Group on Future Priorities (OEWG-FP), informing the SAB that on 15 November 2017, the Working Group had concluded its series of thematic segments with a discussion on any other topics, allowing delegations to cover ideas and proposals that had not been addressed during the previous six sessions. On 6 February 2018, the Co-Chairpersons of the OEWG-FP distributed a document through the Secretariat containing draft recommendations to the Fourth Review Conference. This document is a compilation of all the proposals raised by delegations and the Secretariat during the meetings of the OEWG-FP. The latest meeting of the Working Group, on 5 March 2018, focussed both on the substance of the recommendations, as well as on the process envisaged by the Co-Chairpersons. The OEWG-FP report will be further reviewed, finalised and submitted as a Fourth Review Conference document in line with the OEWG-FP mandate pursuant to Executive Council (hereinafter "the Council") decision EC-82/DEC.2,[106] which requested the OEWG "to supply a holistic, coherent, forward-looking, and action-oriented document consisting of recommendations for consideration" by the Fourth Review Conference.

11.4 In the subsequent discussion, the SAB Chairperson accepted the invitation to the 6 June meeting, and the Chairperson and Vice-Chairperson also noted their intent to brief the Fourth Review Conference itself on the report on developments in science and technology.

Subitem 11(b): Roadmap of the Scientific Advisory Board's work; Subitem 11(c): The Twenty-Eighth Session of the Scientific Advisory Board; and Subitem 11(d): The Scientific Advisory Board's report to the Fourth Review Conference

11.5 The SAB discussed the status of inputs for and approaches to finalising the report on developments in science and technology for the Fourth Review Conference as described under agenda item 13 below. The report will be submitted to the Director-General, whose response will follow in time for the States Parties to review the SAB's advice ahead of a SAB briefing to the OEWG-RC in June 2018.

11.6 To encourage discourse on scientific and technological issues in preparation for inputs and proposals to the Fourth Review Conference by the Secretariat as well as the States Parties, the SAB will continue to hold briefings on its findings from the scientific review process. A preliminary presentation of the findings of the scientific review by the SAB Chairperson and Vice-Chairperson was provided in the "Science for Diplomats" side-event on the margins of the Eighty-Seventh Session of the Council.[107,108] The SAB Chairperson also intends to address the Fourth Review Conference in November 2018.

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

[107] (a) Presentation: www.opcw.org/fileadmin/OPCW/Science_Technology_Diplomacy_Platform/13March2018_-_Science_Review_of_RC4_-_Presentation.pdf; (b) App information for viewing materials from briefing: www.opcw.org/fileadmin/OPCW/Science_Technology_Diplomacy_Platform/

11.7 Recognising the magnitude of the undertaking of the scientific review,[109] the Board and Secretariat discussed the roadmap for the SAB and its Secretary to progress toward the Fifth Review Conference. The Board intends to define its way forward toward the Fifth Review Conference at the Board's Twenty-Eighth Session, in 2019.

11.8 The SAB will hold its Twenty-Eighth Session from 3 to 7 June 2019.

Subitem 11(e): Publications of the work of the Scientific Advisory Board

11.9 Dr Christopher Timperley briefed the SAB on the steps taken to publish the Board's work in peer-reviewed scientific literature.[110] Since the SAB was established in 1998, many of its members had published technical papers in scientific journals in their national capacity in support of the goals of the Convention. Since the last Review Conference, the SAB's reports have contained substantial technical content and many useful scientific references. However, these reports are available only as OPCW documents. To reach an audience of scientists worldwide, and to promote science to uphold the norms of the Convention, the SAB had taken the initiative to publish some of its documents in peer-reviewed scientific literature, especially those that would benefit a broader audience of chemistry practitioners. The authors of these papers would include the full membership of the SAB (at the time advice was provided to the Director-General), the Science Policy Adviser, interns from the Secretariat, and other OPCW staff who had provided significant technical input. The first of these papers, which provides advice on chemical weapons sample stability and storage to increase investigative capabilities worldwide, has been accepted for publication in a chemical forensic-themed issue of the journal *Talanta*. The SAB's advice on riot control agents is currently being prepared for publication, in addition to other scientific publications authored by the SAB.

12. AGENDA ITEM TWELVE – Drafting of the report of the Twenty-Seventh Session of the Scientific Advisory Board

The SAB members reviewed and discussed the draft produced by the drafting committee.

/13March2018_-_Science_Review_for_RC4_-_AR_App.pdf; (c) interactive poster on convergence, www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/13March2018_-_Science_Review_for_RC4_-_Convergence.pdf; (d) interactive poster on enhancing technological capabilities, www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/13March2018_-_Science_Review_for_RC4_-_new_capability.pdf; and (e) interactive poster on chemical production, www.opcw.org/fileadmin/OPCW/Science_Technology/Diplomats_Programme/13March2018_-_Science_Review_for_RC4_-_chemical_prodcution.pdf.

108 For information on the "Science for Diplomats" Initiative, see: www.opcw.org/special-sections/science-technology/science-for-diplomats/.

109 Since the Twenty-Seventh Session (and including the first meeting of the TWG on investigative science and technology), this has consisted of 26 meetings and workshops with a combined participation of 717 (including 285 individuals from 58 States Parties), 31 reports, and 429 presentations and briefings (from 197 individual speakers). The Report to the Fourth Review Conference will contain a bibliography of these reports.

110 See paragraph 13 of: The Impact of the Developments in Science and Technology in the Context of the Chemical Weapons Convention, (EC-82/DG.13, dated 7 June 2016); www.opcw.org/fileadmin/OPCW/SAB/en/ec82dg13_e_.pdf and paragraph 18 of: The Impact of the Developments in Science and Technology in the Context of the Chemical Weapons Convention, (EC-85/DG.8, dated 19 May 2017); www.opcw.org/fileadmin/OPCW/SAB/en/ec85dg08_e_.pdf.

13. AGENDA ITEM THIRTEEN – Drafting of the report to the Fourth Review Conference

The members of the SAB discussed the draft text and recommendations of the report to the Fourth Review Conference, with a focus on the executive summary and its recommendations. The Board submitted the report to the Director-General the week after the conclusion of its Twenty-Seventh Session.

14. AGENDA ITEM FOURTEEN – Any other business

Subitem 14(a): Discussion with the Director-General

14.1 The Director-General met with the SAB on the afternoon of 21 March 2018, delivering remarks to the Board for the final time before his term of office ends in July 2018.[111] Discussing the role of science in the implementation of the Convention, the Director-General reflected on how the OPCW has fostered greater engagement between scientists and policy-makers, sought to institutionalise scientific literacy and ensure that the impact of science and technology is considered in implementing the Convention. He thanked the Board for contributing to and supporting these goals. He also noted that SAB reports are seeing heightened interest amongst States Parties, and any advice to the Fourth Review Conference would be sure to spark discussion. The Director-General requested the Board to continue its productive engagement with States Parties to communicate findings and further drive discourse.

14.2 Recognising that significant challenges remain, for the prevention of the re-emergence of chemical weapons, the Director-General spoke of the need for sustainable solutions and innovative approaches. In this regard, he pointed to the current security situation, and specifically to chemical terrorism as a significant threat that will require a number of approaches where scientific and technical capabilities can be relevant.

14.3 Turning to capacity building—another key aspect of the work of the OPCW—the Director-General spoke of the importance of the OPCW Laboratory and the designated laboratory network. He explained that it is in the interest of the States Parties to have a fully capable Organisation that provides support, including the scientific and technological dimensions of responding to threats of chemical terrorism. The upgrade of the OPCW Laboratory to a Centre for Chemistry and Technology, along with the expansion of the network of designated laboratories, especially in the African and GRULAC regions, is a core element for capacity building. The Director-General noted that regional initiatives to develop laboratories with capabilities for the verification of the Convention could further strengthen capacity building through science and technology.

14.4 Addressing the need for scientific integrity in the work of the OPCW, the Director-General noted that the SAB must also maintain a high level of scientific credibility and encouraged publication to generate visibility and validation of the Board's work within scientific communities.

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111 The full statement is available at: www.opcw.org/fileadmin/OPCW/ODG/Statements/180326_ER_ODG_SPH_SAB27_WEB.pdf.

14.5 Encouraging the SAB to continue working independently and with an open mind, the Director-General asked the SAB to provide its advice freely to him, and to not be restrained from addressing scientific facts of sensitive issues. The Director-General closed with a series of requests for the SAB:

(a) to make the States Parties aware of and encourage them to support the laboratory upgrade project;[112]

(b) to contribute to the Laboratory project by providing recommendations for research and associated capabilities that would add value to the Laboratory as a centre of chemistry and technology amongst the OPCW network of laboratories. These recommendations would be provided in the coming weeks to the Secretary to the SAB; and

(c) to be ready to respond to intersessional requests on topical issues of significance to the implementation of the Convention.

14.6 In the subsequent discussion, the SAB expressed its concerns about the loss of institutional knowledge when Secretariat staff members reach the end of their tenure, especially in regard to contingency operation experience and support to the SAB itself. The Board supports the Director-General's efforts to institutionalise effective knowledge management[113] and stands ready to share its experiences where helpful.

14.7 The SAB thanked the Director-General for his inspirational leadership and ambassadorial role in international diplomacy and international science in the service of peace. The SAB had been constantly impressed by his careful selection of Board members, support for the Board, and encouragement. The Board thanked him for the trust he had placed in it for independent science advice and for making the Board's reports, and his responses to these reports, available to States Parties. The Board viewed this feedback cycle as very important for promoting productive discussion among the States Parties and in some cases, adoption and implementation of the SAB's recommendations. The Board had increased its profile and visibility, both within the OPCW and internationally over the last five years, and this had only been possible thanks to the Director-General's generous support and strong promotion of the Board's work. The Board wished the Director-General all the best for the next stage of his career.

112 (a) Upgrading the OPCW Chemical Laboratory to a Centre for Chemistry and Technology (S/1512/2017, dated 10 July 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1512-2017_e_.pdf; (b) Request from the Director-General to States Parties for Voluntary Contributions to a New Trust Fund for Upgrading the OPCW Chemical Laboratory to a Centre for Chemistry and Technology (S/1561/2017, dated 8 December 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1561-2017_e_.pdf; and (c) Needs Statement for Upgrading the OPCW Chemical Laboratory to a Centre for Chemistry and Technology (S/1564/2017, dated 22 December 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1564-2017_e_.pdf.

113 See paragraphs 6.15 – 6.16 of the Report of the Scientific Advisory Board at its Twenty-Sixth Session (SAB-26/1, dated 20 October 2017). www.opcw.org/fileadmin/OPCW/SAB/en/sab-26-01_e_.pdf.

Subitem 14(b): Visit to the OPCW Laboratory and Equipment Store

14.8 On 21 March, the SAB visited the OPCW Laboratory and Equipment Store, where it received briefings and a tour from the staff. The Laboratory oversees training, equipment certification, maintenance of the OPCW Central Analytical Database (OCAD),[114] and provides instrument support for on-site sampling and analysis inspections. It also organises confidence-building exercises (such as the biotoxin exercise described in paragraph 9.9), facilitates the environmental and biomedical proficiency tests of designated laboratories,[115 116] and provides support to OPCW contingency operations. This high workload should be taken into account for maintaining the necessary high quality laboratory services that the OPCW requires. There is also a need for additional space for expanded activities.

14.9 The SAB supports the project to upgrade the OPCW Laboratory to a Centre for Chemistry and Technology. This would enable the Laboratory to increase capabilities to meet its expanded mandate. An upgraded facility would be better able to facilitate proficiency testing and confidence-building exercises, contingency operations, handling and storage of authentic samples, provision of training, and bring higher scientific visibility to the OPCW.

Subitem 14(c): Election of the Chairperson and Vice-Chairpersons

14.10 In a closed session, the members of the Board elected Mr Cheng Tang as Chairperson and Dr Christophe Curty as Vice-Chairperson for 2019.

Subitem 14(d): Departing SAB members

14.11 The SAB Chairperson bade farewell to Professor Mohammad Abdollahi, Professor David Gonzalez, and Mr Francois Mauritz van Straten, whose terms of office on the SAB will come to a close before the next session of the Board. He thanked all of them for their commitment to the norms of the Convention, their distinguished service, and their substantive contributions to the SAB, especially in support of the scientific review process.

114 The OPCW Central Analytical Database. C. Nyamjav, in Chemical Weapons Convention Chemicals Analysis: Sample Collection, Preparation and Analytical Methods. M. Mesilaakso (ed.). 2005. John Wiley & Sons, Ltd. Chichester, UK. DOI: 10.1002/0470012285.ch7

115 (a) Tentative Schedule for Official OPCW Proficiency Tests in 2018 and 2019 (S/1565/2017, dated 21 December 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1565-2017_e_.pdf; (b) For recent results of an environmental sample proficiency test, see: Evaluation of the Results of the Forty-First Official OPCW Proficiency Test (S/1528/2017, dated 31 August 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1528-2017_e_.pdf; and (c) For the recent results of a biomedical sample proficiency testing, see: Evaluation of the Results of the Second Official OPCW Biomedical Proficiency Test (S/1515/2017, dated 11 July 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1515-2017_e_.pdf.

116 OPCW designated laboratories as at 31 August 2017: (a) Status of Laboratories Designated for Analysis of Authentic Environmental Samples (S/1529/2017, dated 31 August 2017 and Corr.1, dated 8 September 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1529-2017_e_.pdf; and (b) Status of the Laboratories Designated for the Analysis of Authentic Biomedical Samples (S/1516/2017, dated 11 July 2017). www.opcw.org/fileadmin/OPCW/S_series/2017/en/s-1516-2017_e_.pdf.

14.12 The Board bade farewell to Dr Christopher Timperley, its Chairperson since 2015, who will also end his term of office at the conclusion of 2018. The Board expressed its appreciation for his scientific integrity, motivation, and encouragement, which have facilitated a highly dynamic and productive working culture within the SAB.

Subitem 14(e): Briefing to States Parties

14.13 In the margins of the SAB's Twenty-Seventh Session, the SAB Chairperson and Vice-Chairperson briefed States Parties on 22 March 2018,[117] presenting an overview of the activities of the SAB to representatives of the following States Parties: Algeria, Australia, Austria, Bangladesh, Belgium, Brazil, Bulgaria, Cameroon, Canada, Chile, China, Costa Rica, Cyprus, Denmark, Germany, Dominican Republic, India, Iran (Islamic Republic of), Italy, Japan, Latvia, Mexico, Morocco, the Netherlands, Norway, Pakistan, Poland, the Republic of Korea, the Russian Federation, Saudi Arabia, Senegal, Spain, Switzerland, the United Kingdom of Great Britain and Northern Ireland, the United States of America, and Yemen.

Subitem 14(f): Acknowledgements

14.14 The SAB expressed its appreciation to the Director-General, the Deputy Director-General, Mr Nihad Alihodzic, Mr Ken Aoki, Mr Mukremin Balci, Dr Christian R. Boehme, Szymon Bocheński, Mr Sven Devroe, Ms Barbara Hedler, Mr Alejandro Hernandez, Dr Alexander Kelle, Dr Arjan Louter, Mr Mehran Rouzbahani, Dr Albert Swiston, Mr Stuart Thomson, Dr Bonnie Wintle, and Dr Franz Worek for providing informative presentations and discussions during the Board's Twenty-Seventh Session. The SAB acknowledged Mr Joel De Saint Ours, Ms Nadezda Malyutina, Ms Marlene Payva and Ms Siqing Sun of the OPCW Office of Strategy and Policy for their support of and contributions to the Twenty-Seventh Session and its preparations, and for sourcing many of the references provided herein. Additionally, the SAB thanked Dr ChenChen Li, Ms Carina Ramos and Mr Stuart Thomson of the OPCW Laboratory, as well as the Director of Verification, Mr Philippe Denier, and Mr Michael Barrett of the OPCW Equipment Store for their hospitality during the Board's enjoyable visit to the facility.

15. AGENDA ITEM FIFTEEN – Adoption of reports

The SAB considered and adopted the report of its Twenty-Seventh Session and the Report to the Fourth Review Conference.

16. AGENDA ITEM SIXTEEN – Closure of the session

The Chairperson closed the session at 12:20 on 23 March 2018.

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

[117] The Chairperson's briefing is available at: www.opcw.org/fileadmin/OPCW/SAB/en/SAB-27_Briefing_to_States_Parties.pdf.

Annex

LIST OF PARTICIPANTS IN THE TWENTY-SEVENTH SESSION OF THE SCIENTIFIC ADVISORY BOARD[118]

	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.	Dr Khaldoun Bachari	Algerian Public Scientific and Technical Research Centre in the Physico-Chemical-CRAPC, Algiers, Algeria
5.	Dr Renate Becker-Arnold	BASF, Ludwigshafen, Germany
6.	Dr Veronica Borrett[119]	BAI Scientific and Honorary Fellow, University of Melbourne, Australia
7.	Dr Christophe Curty	Spiez Laboratory, Switzerland
8.	Professor Vladimir Dimitrov	Institute of Organic Chemistry at the Centre of Phytochemistry, Bulgarian Academy of Sciences, Sofia, Bulgaria
9.	Professor David Gonzalez	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	U.S. Department of State, Washington, DC, the United States of America
12.	Dr Evandro De Souza Nogueira	Brazilian Ministry of Science, Technology, Innovation and Communications (MCTIC), Brasilia, Brazil
13.	Dr Daan Noort	TNO, Rijswijk, the Netherlands
14.	Professor Ponnadurai Ramasami	University of Mauritius
15.	Dr Syed K. Raza	Chairperson Accreditation Committee, National Accreditation Board for Testing and Calibration Laboratories (NABL), India
16.	Professor Syeda Sultana Razia	Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh
17.	Mr Valentin Rubaylo	State Scientific Research Institute of Organic Chemistry and Technology, Moscow, Russian Federation
18.	Professor Ahmed E. M. Saeed	Sudan University of Science and Technology, Khartoum, Sudan
19.	Dr Yasuo Seto	National Research Institute of Police Science, Tokyo, Japan
20.	Dr Maciej Sliwakowski	Institute of Industrial Organic Chemistry, Warsaw, Poland

[118] Ms Hoe Chee Chua, having sent her apologies, was unable to attend the Twenty-Seventh Session of the SAB.

[119] Chairperson of the Temporary Working Group on investigative science and technology.

	Participant	Institution
21.	Mr Cheng Tang[120]	Office for the Disposal of Japanese Abandoned Chemical Weapons, Ministry of National Defence, China
22.	Dr Christopher Timperley[121]	Defence Science and Technology Laboratory (DSTL), Porton Down, United Kingdom of Great Britain and Northern Ireland
23.	Mr Francois Mauritz van Straten	Chemical Weapons Working Committee, South Africa
24.	Ms Farhat Waqar	Pakistan Atomic Energy Commission
25.	Dr Christian R. Boehm, (guest speaker)	Centre for the Study of Existential Risk, University of Cambridge, United Kingdom of Great Britain and Northern Ireland
26.	Dr Albert Swiston (guest speaker)	Massachusetts Institute of Technology Lincoln Laboratory, Cambridge, Massachusetts, United States of America
27.	Dr Bonnie C. Wintle (guest speaker)	Centre for the Study of Existential Risk, University of Cambridge, United Kingdom of Great Britain and Northern Ireland
28.	Dr Franz Worek (guest speaker)	Bundeswehr Institute of Pharmacology and Toxicology, Munich, Germany
29.	Dr Jonathan Forman (Secretary to the Scientific Advisory Board)	Organisation for the Prohibition of Chemical Weapons, The Hague, the Netherlands

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[120] Vice-Chairperson of the SAB.
[121] Chairperson of the SAB.