OPCW

Scientific Advisory Board

Twenty-Eighth Session
10 – 14 June 2019

SAB-28/1
14 June 2019
Original: ENGLISH

REPORT OF THE SCIENTIFIC ADVISORY BOARD AT ITS TWENTY-EIGHTH SESSION 10 – 14 JUNE 2019

1. AGENDA ITEM ONE – Opening of the session

1.1 The Scientific Advisory Board (SAB) met for its Twenty-Eighth Session from 10 to 14 June 2019 at the OPCW Headquarters in The Hague, the Netherlands.[1] The session was chaired by Mr Cheng Tang, with Dr Christophe Curty as Vice-Chairperson.

Executive Summary

1.2 The SAB received eight invited speaker presentations on topics that included legacy chemical weapons, adducts of toxic chemicals to blood proteins, large scale chemical decontamination, artificial intelligence in chemical analysis, and digital transformation. The Board also received updates from units across the Technical Secretariat (hereinafter, the "Secretariat") to provide inputs and insight for consideration in its science and technology review process.

1.3 Pursuant to the deliberations of the SAB at its Twenty-Eighth Session, the Board recommends the following to the Director-General through this report:

(a) A forensic advisor with broad experience in forensic science and international law should be considered to provide advice to the Director-General and the OPCW. An independent external expert could be considered.

(b) The Secretariat should ensure that forensic issues are included in standard operating procedures (SOPs) or working instructions including those related to on-site sample collection, handling, curation and storage, and annotation, in accordance with forensic best practices.

(c) Relevant OPCW staff should receive training on forensic processes, procedures, and techniques relevant to their role.

(d) Scenarios developed for mission planning and training should be adapted for the purpose of evaluating sampling and detection systems to meet mission conditions.

[1] Scientific Advisory Board Initiates Scientific and Technological Review Process, OPCW News Item, 19 June 2019: www.opcw.org/media-centre/news/2019/06/scientific-advisory-board-initiates-scientific-and-technological-review.

1.4 Further information on these recommendations can be found in paragraphs 9.6 – 9.8.

2. AGENDA ITEM TWO – Adoption of the agenda

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

1. Opening of the session
2. Adoption of the agenda
3. *Tour de table* to introduce SAB members
4. Establishment of a drafting committee
5. Welcome address by the Director-General
6. Overview of developments at the OPCW since the last session of the Scientific Advisory Board
    (a) General updates and the work of the Scientific Advisory Board
    (b) The Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention (the Fourth Review Conference)
    (c) An OPCW scientific repository
    (d) The Article VI verification regime
7. Education and Engagement
    (a) Advisory Board on Education and Outreach (ABEO)
    (b) The Thirty-Third Latin American Congress of Chemistry (CLAQ) and the Tenth Congress of Chemical Sciences, Technology and Innovation
    (c) SAB publications
8. Advice on chemicals
    (a) SAB report on new nerve agents
    (b) Update on schedule change proposals
    (c) Computational studies on new nerve agents and sulphur mustard
9. Investigative science
    (a) The Investigation and Identification Team (IIT)

(b) The second and third meetings of the TWG on investigative science and technology

(c) Scenario-based planning for non-routine missions

(d) Further considerations on investigative science and technology

10. Legacy chemical weapons

(a) Utilising hyperaccumulators to clean up contaminated soil

(b) Information systems on legacy chemical munitions

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

(a) Artificial intelligence (AI) for chemical verification

(b) Established and novel sulphur mustard adducts of human serum albumin for verification of poisoning

(c) Protein adductomics: methodologies for untargeted screening of adducts to serum albumin and haemoglobin in human blood samples

12. Assistance and protection

(a) Evidence-based decontamination strategies for responding to chemical incidents

(b) The International Symposium on Medical Treatment of Chemical Warfare Victims: Challenges and Hopes

(c) Chemical incident preparedness for hospitals (HOSPREP)

13. Digitalisation

(a) Digital transformation powered by AI and related cybersecurity considerations

(b) Digitalisation in the chemical industry

(c) From EDNA to EDIS, the new electronic declarations platform

14. The OPCW Laboratory

(a) Updates from the OPCW Laboratory

(b) The OPCW ChemTech Centre

15. Future work of the SAB

    (a) The Director-General's response to the SAB's recommendations to the Fourth Review Conference

    (b) SAB recommendations and the Verification Division

    (c) SAB recommendations and the Inspectorate

    (d) A roadmap of the work of the SAB

    (e) The Twenty-Ninth Session of the SAB

    (f) Topics of relevance for the report to the Fifth Review Conference[2]

16. Developments in science and technology

17. Drafting of the report of the Twenty-Eighth Session of the SAB

18. Any other business

    (a) Election of the Chairperson and Vice-Chairperson

    (b) Departing SAB Members

    (c) Briefing to States Parties

    (d) Acknowledgements

19. Adoption of the report of the Twenty-Eighth Session of the SAB

20. Closure of the session

3. AGENDA ITEM THREE – *Tour de table* to introduce SAB members

A *tour de table* was undertaken to introduce SAB members and guests. Four new members, Professor Mustafa Ghanei (the Islamic Republic of Iran), Mr Wilford Jwalshik (Nigeria), Dr Andrea Leisewitz (Chile) and Mr Günter Povoden (Austria) 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-Eighth Session.

---

[2] The Fifth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention.

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

5.1 The Director-General of the OPCW delivered the welcome address, thanking the SAB for its contributions to the Fourth Review Conference[3] and its embrace of innovation conveyed through the Board's comprehensive report on developments in science and technology.[4] The Director-General highlighted major developments at the OPCW following the Board's Twenty-Seventh Session[5] in 2018. These included on-going activities of the Secretariat in the Syrian Arab Republic,[6] the decision adopted in June 2018 by States Parties tasking the OPCW with identifying perpetrators of chemical weapons use in the Syrian Arab Republic,[7] a second incident in the United Kingdom involving a new type of nerve agent,[8] and, for the first time in the history of the Chemical Weapons Convention (hereinafter, the "Convention"), States Parties submitting proposals to add new families of nerve agents to the Annex on Chemicals (further addressed under agenda item 8(b).

5.2 Against the backdrop of the aforementioned developments, the Director-General emphasised that the OPCW must not lose sight of other significant challenges facing the Convention, particularly those posed by chemical terrorism and the critical role of chemical security in preventing toxic substances from being diverted for malicious purposes. In recognition of the pressing nature of such issues, he highlighted the importance of a decision taken by the Executive Council (hereinafter, "the Council") in 2017 to address the threat of chemical terrorism,[9] an international conference on

---

3 The Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention.

4 "Report of the Scientific Advisory Board on Developments in Science and Technology for the Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention" (RC-4/DG.1, dated 30 April 2018): www.opcw.org/sites/default/files/documents/CSP/RC-4/en/rc4dg01_e_.pdf. An executive summary brochure is also available; www.opcw.org/sites/default/files/documents/2018/10/SAB_RC4-Executive_Summary_Recommendations_-_web.pdf.

5 "Report of the Scientific Advisory Board at Its Twenty-Seventh Session 19 – 23 March 2018" (SAB-27/1, dated 23 March 2018); www.opcw.org/sites/default/files/documents/SAB/en/sab-27-01_e_.pdf

6 See (a) "Note by the Director-General: Progress in the Elimination of the Syrian Chemical Weapons Programme" (EC‑92/DG.1, dated 24 July 2019): www.opcw.org/sites/default/files/documents/2019/07/ec92dg01%28e%29.pdf. (b) "Report by the Director-General: Status of Implementation of Executive Council Decision EC-83/DEC.5 (Dated 11 November 2016)" (EC-91/DG.17, dated 26 June 2019), (c) "Note by the Director-General: Progress in the Elimination of the Syrian Chemical Weapons Programme" (EC‑91/DG.14, dated 24 June 2019): www.opcw.org/sites/default/files/documents/2019/06/ec91dg14%28e%29.pdf, (d) "Note by the Director-General: Progress in the Elimination of the Syrian Chemical Weapons Programme" (EC‑91/DG.7, dated 24 May 2019): www.opcw.org/sites/default/files/documents/2019/05/ec91dg07%28e%29.pdf. Older progress reports are available at: www.opcw.org/media-centre/featured-topics/syria-and-opcw.

7 "Decision: Addressing the Threat from Chemical Weapons Use" (C-SS-4/DEC.3, dated 27 June 2018); www.opcw.org/sites/default/files/documents/CSP/C-SS-4/en/css4dec3_e_.doc.pdf.

8 "Note by the Technical Secretariat: Summary of the Report on Activities Carried Out in Support of a Request for Technical Assistance by the United Kingdom of Great Britain and Northern Ireland (Technical Assistance Visit TAV/03/18 and TAV/03B/18, "Amesbury Incident")" (S/1671/2018, dated 4 September 2018): www.opcw.org/sites/default/files/documents/S_series/2018/en/s-1671-2018_e_.pdf.

9 "Decision: Addressing the Threat Posed by the Use of Chemical Weapons by Non-State Actors", EC‑86/DEC.9, dated 13 October 2017: www.opcw.org/sites/default/files/documents/EC/86/en/ec86dec09_e_.pdf.

this threat held in June 2018 at the OPCW,[10] and the ongoing activities of the Open-Ended Working Group on Terrorism[11] and its Sub-Working Group on Non-State Actors.[12] Stressing that there is clearly significant work to be done, the Director-General informed the Board that the Secretariat is also working to develop new tools and approaches for assisting States Parties in identifying their own chemical security needs.[13]

5.3 Turning to the work of the SAB, the Director-General prioritised harnessing the power of science to enable the OPCW to maintain and further build upon, the capabilities necessary for effectiveness. Acknowledging that the pace of scientific and technological change shows no sign of slowing, and poses open-ended questions on its implications for the Convention, the Director-General expressed the need for advice for decision-makers that is practical, understandable, and that addresses the needs of the OPCW. He asked the Board to continue its valuable considerations on where emerging tools and new scientific approaches fit into the dynamic and evolving operating environment of the Secretariat, to engage with the Secretariat to understand pertinent issues, to support the project to upgrade the OPCW Laboratory into a Centre for Chemistry and Technology, and especially to draw upon the findings from the temporary working group (TWG) on investigative science and technology for formulating advice (further addressed under agenda item 9(b).

5.4 The Director-General welcomed the new members of the Board and thanked the outgoing SAB members for their scientific rigour in support of the Convention. On behalf of the Secretariat, he expressed sorrow for the passing of Mr Valentin Rubaylo, a dear colleague, a committed member of the SAB, and a good friend whose dedication to the OPCW and the higher cause of global peace and security was clear to all.

---

[10] "Note by the Technical Secretariat: Summary of the Conference on Countering Chemical Terrorism, OPCW Headquarters, The Hague, The Netherlands, 7 – 8 June 2018" (S/1652/2018, dated 16 July 2018); www.opcw.org/sites/default/files/documents/2018/07/s-1652-2018%28e%29.pdf.

[11] For recent updates see: "Report by H.E. Mr Vusi Bruce Koloane Acting Chairperson of the Open-Ended Working Group on Terrorism to the Executive Council at its Ninetieth Session" (EC‑90/WP.1, dated 13 March 2019); www.opcw.org/sites/default/files/documents/2019/03/ec90wp01%28e%29.pdf.

[12] For recent updates see: "Report by H.E. Ambassador Maria Teresa Infante Facilitator of the Sub-Working Group on Non-State Actors of the Open-Ended Working Group on Terrorism: Summary of Intersessional Work (26 September 2017 – 22 June 2018)" (EC‑88/WP.1, dated 3 July 2018); www.opcw.org/sites/default/files/documents/EC/88/en/ec88wp01_e_.pdf.

[13] See for example: (a) "Note by the Director-General: Status of the OPCW's Contribution to Global Anti-Terrorism Efforts" (EC‑90/DG.8, dated 12 February 2019): www.opcw.org/sites/default/files/documents/2019/02/ec90dg08%28e%29.pdf and (b) "Note by the Technical Secretariat: The Implementation of Article VI as a Contribution to Countering Chemical Terrorism: Discussion Paper" S/1622/2018, dated 8 May 2018): www.opcw.org/sites/default/files/documents/S_series/2018/en/s-1622-2018_e_.pdf.

6. AGENDA ITEM SIX – Overview of developments at the OPCW since the last session of the SAB

Subitem 6(a): General updates and the work of the SAB

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-Seventh Session.[5] These included the membership of OPCW reaching 193 States Parties with the accession of the State of Palestine,[14] the resumption of chemical weapon destruction in the United States of America,[15] and the continued deployment of non-routine missions.

6.2 Turning to the work of the SAB, Dr Forman reviewed key points from the Director-General's response to the report of the Twenty-Seventh Session of the SAB,[16] and highlighted accomplishments of the Board in 2018.[17] These included publication of a report on developments in science and technology to the Fourth Review Conference,[4] a report on new types of nerve agents,[18] two meetings of the TWG on investigative science and technology (addressed further under agenda item 9b); the further development of highly interactive and well received engagements with States Parties,[19] briefings on the Board's Fourth Review Conference advice to the Open-Ended Working Group on the Fourth Review Conference (June 2018)[20] and the Industry Cluster (July 2018),[21] and the SAB Chairperson's plenary statement at the Fourth Review Conference (November 2018).[22]

---

14 State of Palestine Joins the Organisation for the Prohibition of Chemical Weapons, OPCW News Item, 21 June 2018: www.opcw.org/media-centre/news/2018/06/state-palestine-joins-organisation-prohibition-chemical-weapons.

15 (a) "Report by the Director-General: Overall Progress with Respect to the Destruction of the Remaining Chemical Weapons Stockpiles" (EC-91/DG.18, dated 28 June 2019), (b) "Decision: Agreed Detailed Plan for Verification of The Destruction of Chemical Weapons at the Blue Grass Chemical Agent-Destruction Pilot Plant Static Detonation Chamber Chemical Weapons Destruction Facility Richmond, Kentucky, The United States of America" (EC-90/DEC.2, dated 13 March 2019).

16 "Note by the Director-General: Response to the Report of the Twenty-Seventh Session of the Scientific Advisory Board" (EC-88/DG.5, dated 9 May 2018): www.opcw.org/sites/default/files/documents/EC/88/en/ec88dg05_e_.pdf.

17 Overview of the Scientific Advisory Board in 2018: www.opcw.org/sites/default/files/documents/2019/05/Scientific_Advisory_Board_2018.pdf.

18 "Response to the Director-General's Request to the Scientific Advisory Board to Provide Advice on New Types of Nerve Agents" (SAB-28/WP.1, dated 3 July 2018).

19 See "Science for Diplomats initiative" and "Science and Technology Reference Materials" at www.opcw.org/resources/science-and-technology.

20 Presentation available at: www.opcw.org/sites/default/files/documents/SAB/en/20180606_OEWG-RC-Science_and_Technology.pdf.

21 Presentation available at: www.opcw.org/sites/default/files/documents/2018/07/20180709_SAB_Recommendation_Briefing_Industry_Cluster.pdf

22 The statement and accompanying slides are available at: www.opcw.org/sites/default/files/documents/2019/01/26_November_2018_SAB_Chair_RC4_Remarks.pdf (statement), and www.opcw.org/sites/default/files/documents/2018/11/26_November_2018_SAB_Chair_RC4_Slides%20%28002%29.pdf (slides).

6.3 Dr Forman continued with updates on science and technology-related engagement of the Secretariat and the SAB. At the Fourth Review Conference, this included the organisation of and participation in side events on the partnership with the International Union of Pure and Applied Chemistry (IUPAC),[23] the increasing digitalisation of science and industry, [24] and the launch of the VERIFIN Blue Book.[25] After addressing the leadership of the American Chemical Society (ACS) in March 2018,[26] the Director-General spoke to the Royal Society of Chemistry (RSC) in May 2018,[27] and the Secretariat continues to explore productive ways to collaborate with IUPAC and other prominent chemical societies. Engagement activities with other science and security focused organisations since the SAB's Twenty-Seventh Session have included attendance at the Second Meeting of the Chemical Forensics International Technical Working Group (CFITWG) in August 2018, providing a series of presentations on science advice[28] and the Hague Ethical Guidelines[29] at the Biological Weapons Convention (BWC) Meeting of Experts (Geneva) in August 2018, and participation in the Spiez Laboratory's Fourth United Nations Secretary-General's Mechanism (UNSGM) Designated Laboratories[30] and Third CONVERGENCE[31] Workshops in September 2018. Engagement activities also

---

23 (a) OPCW and IUPAC Presentation: Reflecting on and Taking Forward a Partnership with the Scientific Community, 21 November 2018: www.opcw.org/sites/default/files/documents/2018/11/20181121%20-%20IUPAC%20-%20OPCW%20-%20Presentation.pdf, (b) "Building Broader and Deeper Links Between OPCW and IUPAC", R. M. Hartshorn, J. Forman, *Chemistry International*, 2019, *41(2)*, 30-33. DOI: 10.1515/ci-2019-0210, and (c) see also: www.opcw.org/sites/default/files/documents/2019/07/OPCW-IUPAC%20Cooperation.pdf.

24 Digitalization and Disarmament: The Future is Now, are we Prepared for it? 22 November 2018: http://unicri.it/news/article/Disarmament_AI_robotics_CWC.

25 The Significance of Verification - The Role of the Scientific Advisory Board, 22 November 2018: www.opcw.org/sites/default/files/documents/2019/01/Significance%20of%20Verification%20-%20The%20Role%20of%20the%20Scientific%20Advisory%20Board.pdf

26 (a) Remarks to Committee on International Affairs are available at: www.opcw.org/sites/default/files/documents/ODG/uzumcu/180319.FR.ODG.SPH.ACS.WEB.pdf. (b) Opening remarks to a symposium on ethics in chemistry are available at (video): https://www.youtube.com/watch?v=HSMIUbw9HCg.

27 Remarks available at: www.opcw.org/sites/default/files/documents/ODG/uzumcu/180523.FR.ODG.Speech_RSC.pdf. See also "A world free of chemical weapons", 17 July 2018: https://www.rsc.org/news-events/opinions/2018/jul/a-world-free-of-chemical-weapons/.

28 The Secretariat and members of the SAB provided briefings on the SAB's report to the Fourth Review Conference: https://www.unog.ch/80256EDD006B8954/(httpAssets)/036F578EC41216C7C12582E6003569DC/$file/20180810_OPCW_SAB_Science_Review_BWCMX2.pdf and organised a side event on disarmament and technological change: https://www.unog.ch/80256EDD006B8954/(httpAssets)/AB8AB92C1D82E15EC12582EA00283CF4/$file/2018+MX+side+event+OPCW_MX2.pdf.

29 Presentation available at: https://www.unog.ch/80256EDD006B8954/(httpAssets)/950C23C63756F06EC12582E4006AC2F2/$file/Hague_Ethical_Guidelines_BWCMX2-print.pdf.

30 UNSGM Designated Laboratories 4th Workshop, 9 – 11 September 2018; https://www.labor-spiez.ch/pdf/en/rue/UNSGM_Designates_Laboratories_4th_workshop_Report.pdf. A summary presentation held on at the Biological Weapons Convention is also available: https://www.unog.ch/80256EDD006B8954/(httpAssets)/C1EEA82CBB7771C1C125835F0037A826/$file/20181206_UNSGM-WS_BWC-MSP_INC.pdf.

31 (a) CONVERGENCE Report on the 3rd Workshop, 11 – 14 September 2018: https://www.labor-spiez.ch/pdf/en/rue/Spiez_CONVERGENCE_Report_on_the_3rd_workshop_2018.pdf. (b) A summary

included attendance of the BWC Meeting of States Parties (Geneva) in December 2018), participation in a breakout session on biotechnologies at the "Capturing Technology: Rethinking Arms Control" workshop (Berlin) in March 2019,[32] the SAB Chairperson's participation at the International Chemical Weapons Demilitarisation Conference (London) in May 2019, and participation in a panel discussion on future challenges at the Forty-Third International Committee of Military Medicine (ICMM) World Congress on Military Medicine (Basel) in 2019.[33]

6.4 Science and technology-related engagement activities in 2019 include participation in the Forty-Seventh IUPAC World Chemistry Congress and Fiftieth General Assembly at Palais des Congrès in Paris in July,[34] continued engagement with the BWC at the 2019 Meeting of Experts,[35] and presentations at the ACS Fall 2019 meeting in August 2019, where the Third CFITWG workshop will also be held. The Secretariat has also organised a number of science-related activities with the participation of SAB members as part of its capacity building programmes; these include events on women in chemistry,[36] and continued exploration of topics in green and sustainable chemistry.[37]

6.5 Dr Forman concluded with updates on voluntary contributions to the SAB Trust Fund[38] received from Australia, a voluntary contribution for science communication activities from the Kingdom of Saudi Arabia and the decisions of the European Union (EU) Council that provide funding for SAB's TWGs.[39] The EU decisions in 2015 and

---

of the workshop was also presented in cooperation with the TWG on investigative science and technology as part of a Fourth Review Conference side event on 23 November 2018: www.opcw.org/sites/default/files/documents/2018/12/20181123-Science_for_Diplomats_at_RC4-Convergence%20and%20solving%20chemcial%20mysteries.pdf.

32 For further information see https://rethinkingarmscontrol.de/.

33 For further information see https://www.icmm2019.ch/en/index.html.

34 For further information see https://iupac.org/event/iupac-2019-paris-france/.

35 For further information see https://www.unog.ch/80256EE600585943/(httpPages)/E8A05357EECA5490C12583BE00578053?OpenDocument.

36 "Note by the Technical Secretariat: Invitation to Apply for a Symposium on Women in Chemistry and a Basic Analytical Chemistry Course for Women Chemists, The Hague and Rijswijk, the Netherlands, 24 – 28 June 2019" (S/1720/2019, dated 15 February 2019): www.opcw.org/sites/default/files/documents/2019/02/s-1720-2019%28e%29.pdf.

37 (a) "Note by the Technical Secretariat: Call for Nominations for a Workshop on Green and Sustainable Chemistry: Fostering Chemical Safety and Security Through Innovation, The Hague, The Netherlands 4 – 5 December 2018" S/1656/2018, dated 10 August 2018: https://www.opcw.org/sites/default/files/documents/2018/08/s-1656-2018%28e%29.pdf, and (b) "Note by the Technical Secretariat: Invitation to apply for a Forum on Peaceful Uses of Chemistry: Potential Contribution of the OPCW to the Achievement of the United Nations Sustainable Development Goals, The Hague, The Netherlands 26 October 2018" (S/1649/2018, dated 10 July 2018): www.opcw.org/sites/default/files/documents/2018/07/s-1649-2018%28e%29.pdf.

38 "Note by the Technical Secretariat: Call for Voluntary Contributions to the Trust Fund of the Scientific Advisory Board" (S/1703/2019, dated 10 January 2019): www.opcw.org/sites/default/files/documents/2019/01/s-1703-2019%28e%29.pdf.

39 (a) Council Decision (CFSP) 2015/259 of 17 February 2015 in support of activities of the Organisation for the Prohibition of Chemical Weapons (OPCW) in the framework of the implementation of the EU Strategy against Proliferation of Weapons of Mass Destruction: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015D0259; Project III. (b) Council Decision (CFSP) 2019/538 of 1 April 2019 in support of activities of the Organisation for the Prohibition of Chemical Weapons (OPCW)

2019 also provided funding for the Secretariat's crowd engagement activities. The 2015 decision was an exploratory education project collecting air quality data with low-cost sensors as a means to demonstrate the recognition of signatures of chemical change and triggering events.[40] The recently awarded 2019 EU decision includes a plant-based marker of chemical exposure crowdsourcing challenge.[41] Several SAB members will work with the Secretariat to move this project forward in 2020.

6.6 In the subsequent discussion, it was suggested that if a suitable proposal is received and awarded from the plant biomarker challenge, it may be possible to run live agent tests through activities of SAB members working in suitable facilities.

Subitem 6(b): The Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention (the Fourth Review Conference)

6.7 Mr Szymon Bocheński (Senior Policy Officer in the Office of Strategy and Policy) briefed the SAB on the proceedings of Fourth Review Conference, held from 21 to 30 November 2018,[42] at which States Parties carried out a review of the implementation of the Convention since the Third Review Conference in 2013.[43] He explained that States Parties were unable to reach a consensus, and no outcome document was produced. In its absence, a Chairperson's report of the proceedings was issued.[44] This report contains a number of non-agreed and non-binding recommendations that had been discussed during the preparatory phase of the Review Conference and at the Review Conference itself. The Board was informed that in accordance with paragraph 22 of Article VII of the Convention, the Conference reviewed relevant scientific and technological developments.

6.8 During the proceedings, the SAB's report to the Review Conference[4] was noted, references to the SAB and its work were included in the Chairpersons report and in a number of national statements, and SAB recommendations were included in the final report of the Open-Ended Working Group on Future Priorities (OEWG-FP).[45]

---

in the framework of the implementation of the EU Strategy against Proliferation of Weapons of Mass Destruction: https://eur-lex.europa.eu/eli/dec/2019/538/oj; Project VII.

40 Activity on "Chemical informatics for facilitating international collaboration" under Project III: Science and technology. Students from the Kings University (Edmonton, Canada) and the Ibero-American University (Mexico City, Mexico) participated.

41 Activity on "Plant biomarker challenge" under Project VII: Science and technology.

42 For further information see: www.opcw.org/rc-4.

43 "Note by the Technical Secretariat: Review of the Operation of the Chemical Weapons Convention since the Third Review Conference" (RC-4/S/1, dated 6 November 2018). See paragraphs 3.1 to 3.30 for information related to science. Technology and the SAB: www.opcw.org/sites/default/files/documents/2018/11/rc4s01%28e%29.pdf.

44 "Chairperson's Report of the Proceedings of the Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention (Fourth Review Conference)" (RC-4/3/Rev.1, dated 30 November 2018). Paragraphs and sub-paragraphs 9.23, 9.45, 9.59(m), 9.84, and 9.100(a) make reference to the SAB: www.opcw.org/sites/default/files/documents/2018/12/rc403r1%28e%29.pdf.

45 "Open-Ended Working Group on Future Priorities of the OPCW Recommendations to the Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention" (RC-4/WP.1, dated 16 July 2018); www.opcw.org/sites/default/files/documents/2018/07/rc4wp01%28e%29.pdf.

References to the SAB also appeared in working papers from States Parties expressing a variety of views on issues covering the Annex on Chemicals,[46] central nervous system (CNS)-acting chemicals,[47] sea-dumped chemical weapons,[48] the OPCW and science and technology,[49] and strengthening verification.[50]

Subitem 6(c): An OPCW scientific repository

6.9 Dr Zaven Hakopov, Senior Knowledge Management Officer, discussed a proposal for a Chemical Information Repository (CIR). For the purpose of sustainable preservation of explicit expert knowledge and information either used or created by the Secretariat and its key stakeholders, a modern digital information and data repository can be implemented to provide organised long-term storage and persistent access to non-confidential scientific and technical information. The information would consist of, but not be limited to: scientific publications, technical notes, reports, articles, proceedings, other types of literature such as training materials and guides, as well as data sets and media in areas of science and technology relevant to the implementation of the Convention.

6.10 The CIR would encompass knowledge on the production cycles of chemicals, chemicals that have been used as chemical weapon agents, chemical analysis, and related areas such as the legal frameworks set out in the Convention. This repository would also contain collections of sectoral information relevant to specific programmes and projects within the Secretariat, such as, for example, demilitarisation and information and data obtained from old, abandoned, and sea-dumped chemical weapons. The repository can be organised with restricted and unrestricted collections. The CIR could facilitate access to and exchange of scientific and technical information between the Secretariat and its stakeholders, including the State Parties, and in this context it could also contribute to capacity building and the exchange of scientific knowledge to support Article XI objectives.

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

(a) The SAB expressed support for the CIR concept. This would be a useful platform to organise the wealth of scientific papers and patents collected

---

46 "Russian Federation: Considerations Regarding the Schedules of Chemicals of the Annex on Chemicals to the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction" (RC-4/NAT.35, dated 5 December 2018).

47 (a) "Joint paper: Aerosolisation of Central Nervous System-Acting Chemicals for Law Enforcement Purposes" (RC-4/NAT.26, dated 30 November 2018): www.opcw.org/sites/default/files/documents/2018/11/rc4nat26%28e%29.pdf and (b) "Russian Federation: Aerosolisation of Chemical Nervous System-Acting Chemicals for Law Enforcement Purposes" (RC‑4/NAT.9, dated 21 November 2018): www.opcw.org/sites/default/files/documents/2018/11/rc4nat09%28e%29.pdf.

48 "Joint Paper: Broadening International Cooperation on Sea-Dumped Chemical Weapons and Promoting the OPCW as a Forum for Voluntary Cooperation on the Issue" (RC-4/WP.3/Rev.2, dated 28 of November 2018): www.opcw.org/sites/default/files/documents/2018/11/rc4wp03r2%28e%29.pdf.

49 "Islamic Republic of Iran: The OPCW and Science and Technology" (RC-4/WP.4, dated 12 November 2018); www.opcw.org/sites/default/files/documents/2018/11/rc4wp04%28e%29.pdf.

50 "Switzerland: Strengthening the OPCW's Verification Regime (RC-4/WP.9, dated 14 November 2018); www.opcw.org/sites/default/files/documents/2018/11/rc4wp09%28e%29.pdf.

during the scientific review process, in addition to providing access to archives of information related to the work of the SAB.

(b) The scope of content, the acceptance or selection of content, and the subject categories within the CIR require consideration and definition. Several SAB members expressed interest in reviewing and providing comments on the organisation and structure of the CIR.

Subitem 6(d): The Article VI verification regime

6.12 Ms Barbara Hedler and Mr Larry Denyer (OPCW Industry Verification Branch) briefed the SAB on developments and changes to industry verification under the Convention since the Third Review Conference.[51] Through the industry cluster, the Secretariat continues to seek consensus amongst States Parties recommendations, coming from the SAB, the National Authorities, the chemical industry, as well as recommendations proposed within the framework of the OEWG-FP.

6.13 Recommendations from the reports of the TWGs on convergence[52] and verification[53] have been topics of industry cluster discussions since 2015. Significant consideration has been given to recommendations on adopting more analytical approaches to verification, approaches for the declaration of complex mixtures of discrete organic chemicals (DOC), the verification aspects of "production by synthesis", the effective use of sampling and analysis, and relevant developments in science and technology. Newer topics that have been raised include highly active pharmaceutical ingredients, digitalisation, and applications of distributed ledger technology for reporting chemical trade. States Parties have a variety of views and these discussions are in a very early stage. While some of the SAB's recommendations have been discussed extensively within the Industry Cluster, others still need further development and agreement.

6.14 The Secretariat has initiated a broad review of Article VI verification as part of its ongoing commitment to continual improvement. States Parties have also contributed to the consultations. For example in March 2019, the Argentine Republic introduced a proposal regarding the implementation of the methodology for the selection of other

---

51 For further information see (a) "Note by the Technical Secretariat: Review of the Operation of the Chemical Weapons Convention since the Third Review Conference" (RC-4/S/1, dated 6 November 2018): www.opcw.org/sites/default/files/documents/2018/11/rc4s01%28e%29.pdf. (b) " Draft Report of the OPCW on the Implementation of the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction in 2018" (EC-91/CRP.1, dated 14 June 2019): www.opcw.org/sites/default/files/documents/2019/06/ec91crp01%28e%29.pdf.

52 "Convergence of Chemistry and Biology: Report of the Scientific Advisory Board's Temporary Working Group" (SAB/REP/1/14, dated 26 June 2014): www.opcw.org/sites/default/files/documents/SAB/en/TWG_Scientific_Advsiory_Group_Final_Report.pdf. A quick reference guide to its recommendations is also available: www.opcw.org/sites/default/files/documents/SAB/en/Convergence_of_Chemistry_and_Biology_1-01.pdf.

53 "Verification Report of the Scientific Advisory Board's Temporary Working Group" (SAB/REP/1/15, dated 11 June 2015): www.opcw.org/sites/default/files/documents/SAB/en/Final_Report_of_SAB_TWG_on_Verification_-_as_presented_to_SAB.pdf. A quick reference guide to its recommendations is also available: www.opcw.org/sites/default/files/documents/SAB/en/VER_Poster_5102015.pdf.

chemical production facilities for inspection, which seeks to automate the site selection procedure so that the frequency of inspections at a given plant site is more equitable with the distribution of declared sites, and to explore the modification of the site selection methodology to preferentially select sites of higher versus lower relevance to the object and purpose of the Convention. Discussions and further study of this issue are under way as part of a broader discussion on site selection issues.[54]

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

(a) Site selection methodology is continually under review by the Council, allowing updates to be proposed and simulations run in order to assess the impact and usefulness of changes.

(b) Another approach to addressing concerns about inspection frequency could come through a 2015 recommendation of the SAB's TWG on verification,[53] which suggested that the Secretariat visit National Authorities in order to obtain assurance on the accuracy and completeness of declarations, which could include audit-type visits. Mr Denyer noted that the formulation of proposals is being considered.

(c) Regarding recent proposals to make changes to the Schedules of Chemicals in the Annex on Chemicals to the Convention (see agenda item 8(b)), the number of sites that might be declared would need to be seen before the full impact of the changes are known.[55] However, the Secretariat's current assessment suggests that none of the chemicals concerned have industrial or commercial uses, therefore impactful changes to declarations are not expected.[56]

(d) It was noted that no proposals have been discussed in response to the SAB's advice to the Fourth Review Conference on high-production-volume Schedule 3 chemicals.[57]

---

54 "Note by the Director-General: Report on the Performance of the Revised Methodology for the Selection of Other Chemical Production Facilities for Inspection "(S/1715/2019, 6 February 2019): www.opcw.org/sites/default/files/documents/2019/02/s-1715-2019%28e%29.pdf

55 Comments from industry have been requested by National Authorities in some States Parties. See for example: "Impact of Proposed Additions to the "Annex on Chemicals" to the Chemical Weapons Convention (CWC) on Legitimate Commercial Chemical, Biotechnology, and Pharmaceutical Activities Involving "Schedule 1" Chemicals (Including Schedule 1 Chemicals Produced as Intermediates)", United States Industry and Security Bureau, August 2019: https://www.federalregister.gov/documents/2019/08/14/2019-17256/impact-of-proposed-additions-to-the-annex-on-chemicals-to-the-chemical-weapons-convention-cwc-on.

56 (a) "Evaluation of the Proposal Submitted by Canada, the Netherlands, and the United States of America for a Change to the Annex On Chemicals of the Chemical Weapons Convention" (EC-M-62/DG.1, dated 14 December 2018). (b) "Evaluation of the Proposals Submitted by the Russian Federation for a Change to the Annex on Chemicals of the Chemical Weapons Convention" (EC-M-63/DG.1 and Corr.1, both dated 29 January 2019, and Corr.2, dated 1 February 2019).

57 See paragraph 24 of RC-4/DG.1.

7. AGENDA ITEM SEVEN – Education and engagement

Subitem 7(a): Advisory Board on Education and Outreach (ABEO)

7.1 Ms Francesca Capano (Office of Strategy and Policy) updated the SAB on the ABEO, which has met twice since March 2018.[58] Recent activities include the production of an education and outreach brochure for State Parties[59] and remarks to the Fourth Review Conference.[60] The ABEO had also recommended that the Secretariat and its stakeholders give increased prominence to the role and function of the general purpose criterion in its education and outreach activities, including addressing its importance in public statements. Additionally, four intersessional working groups were to consider the history of chemical weapons use, education and outreach resources, active learning approaches, and new educational materials with a view to providing advice to the Director-General on enhancing external engagement and outreach. Areas of future consideration include OPCW e-learning resources and exploring links between the work of the OPCW and the United Nations Sustainable Development Goals,[61] the United Nations Secretary General's disarmament agenda,[62] disarmament education, and the education and outreach programmes of other international organisations. The Board's next meeting will take place in August 2019.

7.2 Additionally, Ms Capano informed the SAB of the education and outreach materials that are now available on the OPCW website,[63] including an updated version of the Chemistry in Conflict education module.[64]

7.3 In the subsequent discussion, SAB members expressed interest in the availability of educational materials that have been or could be used to develop university-level chemical safety and security courses in the chemical sciences.

Subitem 7(b): The Thirty-Third Latin American Congress of Chemistry (CLAQ) and 10th Congress of Chemical Sciences, Technology and Innovation

7.4 Professor Isel Alonso reported to the SAB on the Thirty-Third CLAQ and Tenth Congress of Chemical Sciences, Technology and Innovation, which she co-organised

---

58 (a) "Report of the Seventh Session of the Advisory Board on Education and Outreach" (ABEO-7/1, dated 28 February 2019): www.opcw.org/sites/default/files/documents/2019/04/abeo-7-01%28e%29.pdf; (b) "Report of the Sixth Session of the Advisory Board on Education and Outreach" (ABEO-6/1, 30 August 2018): www.opcw.org/sites/default/files/documents/2018/09/abeo-6-01%28e%29.pdf.

59 Education and Outreach for a World Free of Chemical Weapons – Role of States Parties, November 2018: www.opcw.org/sites/default/files/documents/2018/11/Education%20and%20Outreach%20for%20a%20World%20Free%20of%20Chemical%20Weapons%20%E2%80%93%20Role%20of%20States%20Parties%20%28Single%20Pages%20Format%29_2.pdf.

60 See: www.opcw.org/sites/default/files/documents/2018/11/rc4wp12%28e%29.pdf.

61 United National Sustainable Development Goals Knowledge Platform: https://sustainabledevelopment.un.org/.

62 Securing Our Common Future: An Agenda for Disarmament: https://www.un.org/disarmament/sg-agenda/en/.

63 For further information see: www.opcw.org/resources/education-and-outreach

64 "Chemistry in Conflict an OPCW educational module", Revised Third Edition November 2018: www.opcw.org/sites/default/files/documents/2018/11/Chemistry%20in%20Conflict%20workbook_3rd%20Edition_November%202018_2.pdf.

in Havana, Cuba in October 2018.[65] This Congress provided a special opportunity to share the recent advances in pure and applied chemistry. Delegates from 32 countries attended, and the 1,100 participants provided 1,131 oral presentations and posters. Technical sessions covered analytical chemistry, chemical education, chemical technology and engineering, initiative and innovation, computational and theoretical chemistry, inorganic chemistry, environmental chemistry, materials chemistry, nano- and supramolecular chemistry, natural products, pharmaceuticals and foods, organic chemistry, physical chemistry, and radiochemistry. The Congress also included two special symposia, on "Biochemistry, Molecular Biology and Materials for Bioengineering, and Nanomedicine".

7.5 The opening plenary lecture, "Molecular machines in Biology and Chemistry", was presented by 2016 Chemistry Nobel Laureate Dr Jean-Pierre Sauvage. Other plenary lectures included "Sugars & proteins: towards a synthetic biology" (Benjamin G. Davis), "Taming the Beast: Controlling Carbenes by Light, Temperature, and Solvent Interactions" (Wolfram Sander) and "The Diels-Alder reaction applied to polymers from renewable resources: thermal reversibility, mendability and recyclability" (Alessandro Gandini). The closing plenary lecture, "Contribution of Chemistry to Vaccine Development in Cuba: towards a Hexavalent Conjugate Vaccine Containing 15 Antigens" was presented by Vicente Vérez Bencomo of the Instituto Finlay de Vacunas, Cuba (the creator of the internationally recognised synthetic vaccine against *haemophilus influenza* type B).

7.6 The 2018 SAB Chairperson Dr Christopher Timperley and SAB member Dr Zrinka Kovarik were in attendance. Dr Timperley presented lectures on "Chemistry and Diplomacy: the work of the Scientific Advisory Board of the Organisation for the Prohibition of Chemical Weapons" [66] and "Evidence of VX Nerve Agent use from Contaminated White Mustard Plants".[67] Dr Kovarik presented a lecture on "Pseudo-Catalytic Nerve Agents Scavenging by Acetylcholinesterase Assisted with Aldoximes".[68] The attendance of SAB members provided opportunities to discuss aspects of science and technology relevant to the OPCW with the Cuban Society of Chemistry and the Cuban National Authority.

7.7 The Thirty-Fourth CLAQ will take place in July 2020 in Cartagena de Indias City in Colombia.

7.8 In the subsequent discussion, it was recognised that the organisation of international conferences offers opportunities to raise awareness of the OPCW, and to help promote productive international science collaboration.

---

65 (a) "Memorias del 33º Congreso Latinoamericano de Química (33-CLAQ) y X Congreso de Ciencias Químicas, Innovación y Tecnología (QUIMICUBA'2018)" L. M. Alonso; *Encuentro con la Química*; 2019, *5(1)*. (b) "QUIMICUBA 2018", I. P. Alonso, M. Rojas, R. Rodés; *Carta al Editor*, 2018, *6(3)*, 1-2. For additional information, see http://www.chemistrycuba.com/.

66 "Chemistry and Diplomacy", J. E. Forman, C. M. Timperley, S. Sun, D. van Eerten; *Pure Appl. Chem.*, 2018, *90(10)*, 1507-1525. DOI: 10.1515/pac-2018-0902.

67 "Evidence of VX nerve agent use from contaminated white mustard plants". M. R. Gravett, F. B. Hopkins, A. J. Self, A. J. Webb, C. M. Timperley, M. J. Baker; *Proc. R. Soc. A*; 2014, *470(2168)*. DOI: 10.1098/rspa.2014.0076.

68 For further information on Dr Kovarik's research in this area see: https://www.imi.hr/en/projekt/design-synthesis-and-evaluation-of-new-antidotes-in-nerve-agent-and-pesticide-poisoning-cholinesterase/.

Subitem 7(c): SAB Publications

7.9 Dr Forman updated the SAB on the status of publications of the Board's work in peer-reviewed scientific publications. Recognising that the SAB's reports contain substantial technical content and many useful scientific references, yet are available only as OPCW documents, the Director-General had encouraged the SAB to bring these reports into scientific literature.[69] The initiative serves to reach a worldwide audience of scientists and raise awareness of the important role of science in supporting the Convention. Publications include: a special issue of the IUPAC journal *Pure and Applied Chemistry* containing a series of papers from the 2017 SAB workshop on emerging technologies,[70] contributions to an ACS symposium series book (based on a symposium in which the Secretariat had participated in 2015),[71] and the SAB's advice on isotopic labelling and stereoisomers of scheduled chemicals,[72] sample storage and stability,[73] assistance and protection,[74] and riot control agents.[75]

---

69 See paragraph 13 of: "Note by the Director-General: 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 "Note by the Director-General: 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.

70 *Pure and Applied Chemistry*, 2018, *90(10)*: https://iupac.org/etoc-alert-pure-and-applied-chemistry-oct-2018/.

71 "Chemical Disarmament in a Technologically Evolving World", J. E. Forman, C. M. Timperley; Chapter 1 in *Responsible Conduct in Chemistry Research and Practice: Global Perspectives*, E. T. Contis, A. Campbell, D. Phillips, B. Miller, L. Brown (Editors), ACS Symposium Series, 2018, *1288*, 3-35. DOI: 10.1021/bk-2018-1288.ch001.

72 "Advice from the Scientific Advisory Board of the Organisation for the Prohibition of Chemical Weapons on Isotopically Labelled Chemicals and Stereoisomers in Relation to the Chemical Weapons Convention", C. M. Timperley, J. E. Forman, M. Abdollahi, A.S. Al-Amri, I. P. Alonso, A. Baulig, V. Borrett, Veronica Borrett, F. A. Cariño, C. Curty, D. Gonzalez, Z. Kovarik, R. Martínez-Álvarez, R. Mikulak, N. M. Fusaro Mourão, P. Ramasami, S. Neffe, S. K. Raza, V. Rubaylo, K. Takeuchi, C. Tang, F. Trifirò, F. Mauritz van Straten, P. S. Vanninen, V. Zaitsev, F. Waqar, M. Saïd Zina, S. Holen, H. A. Weinstein; *Pure Appl. Chem.*, 2018, *90(10)*, 1647-1670. DOI: 10.1515/pac-2018-0803.

73 "Advice on Chemical Weapons Sample Stability and Storage Provided by the Scientific Advisory Board of the Organisation for the Prohibition of Chemical Weapons to Increase Investigative Capabilities Worldwide, C. M. Timperley, J. E. Forman, M. Abdollahi, A.S. Al-Amri, I. P. Alonso, A. Baulig, V. Borrett, F. A. Cariño, C. Curty, D. González Berrutti, Z. Kovarik, R. Martínez-Álvarez, R. Mikulak, N. M. Fusaro Mourão, P. Ramasami, S. Neffe, S. K. Raza, V. Rubaylo, K. Takeuchi, C. Tang, F. Trifirò, F. Mauritz van Straten, P. S. Vanninen, V. Zaitsev, F. Waqar, M. Saïd Zina, M.-M. Blum, H. Gregg, E. Fischer, S. Sun, P. Yang; *Talanta*, 2018, *188*, 808-832. DOI: 10.1016/j.talanta.2018.04.022.

74 (a) "Advice on assistance and protection provided by the Scientific Advisory Board of the Organisation for the Prohibition of Chemical Weapons: Part 1. On medical care and treatment of injuries from nerve agents", C. M. Timperley, J. E. Forman, M. Abdollahi, A. S. Al-Amri, A. Baulig, D. Benachour, V. Borrett, F. A. Cariño, M. Geist, D. Gonzalez, W. Kane, Z. Kovarik, R. Martínez-Álvarez, N. M. F. Mourão, S. Neffe, S. K. Raza, V. Rubaylo, A. G. Suárez, K. Takeuchi, C. Tang, F. Trifirò, F. M. van Straten, P. S. Vanninen, S. Vučinić, V. Zaitsev, M. Zafar-Uz-Zaman, M. S. Zina, S. Holen; *Toxicology*, 2019, *415*, 56-69. DOI: 10.1016/j.tox.2019.01.004. (b) "Advice on assistance and protection from the Scientific Advisory Board of the Organisation for the Prohibition of Chemical Weapons: Part 2. On preventing and treating health effects from acute, prolonged, and repeated nerve agent exposure, and the identification of medical countermeasures able to reduce or eliminate the longer term health effects of nerve agents", C. M. Timperley, M. Abdollahi, A. S. Al-Amri, A. Baulig, D. Benachour, V. Borrett, F. A. Cariño, M. Geist, D. Gonzalez, W. Kane, Z. Kovarik, R. Martínez-Álvarez, N. M. F. Mourão, S. Neffe, S. K. Raza, V. Rubaylo, A. G. Suárez, K. Takeuchi, C. Tang, F. Trifirò, F. M. van Straten, P. S. Vanninen, S. Vučinić, V. Zaitsev, M. Zafar-Uz-Zaman, M. Saïd Zina, S. Holen, J. E. Forman, W. S. Alwan, V. Suri; *Toxicology*, 2019, *413*, 13-23. DOI: 10.1016/j.tox.2018.11.009.

Dr Forman also informed the SAB of a call for papers from the Journal of Chemical Education requesting chemical security-related educational materials that can be used in high school and university-level chemistry courses.[76]

7.10 In the subsequent discussion, the current SAB members welcomed the practice of publishing relevant outputs of the Board's work in peer-reviewed scientific publications and encouraged the continuation and reinforcement of this practice. The SAB encouraged publication of the additional reports resulting from the scientific review process for the Fourth Review Conference.

8. AGENDA ITEM EIGHT – Advice on chemicals

Subitem 8(a): Scientific Advisory Board report on new nerve agents

8.1 In May 2018, following a review of the findings of the March 2018 technical assistance visit in response to the Salisbury incident, the SAB was requested to provide advice on toxic chemicals that have been identified as, or are suspected of belonging to, a new generation of nerve agents.[77] Mr Tang and Dr Forman reviewed the SAB's report[18] discussing the feedback and responses it received.

8.2 In the Director-General's request, the SAB was tasked to take guidance from chemicals reviewed by the Board in 2011[78] and any close analogues. These chemicals, had been associated in open literature with "Novichok" terminology, which was also used to describe the chemical identified in the Salisbury Incident. This provided a starting point for consideration. Public information on the chemical structures associated with Novichok terminology, peer-reviewed scientific publications, and patent literature were reviewed, and a set of relevant chemical families were identified. However, for some chemical structures falling under these families, no experimental methods or data have been reported in peer-reviewed scientific or open literature, and almost no technical information (in particular, toxicological information) was available. The SAB did not identify any currently established uses of the chemical families identified for purposes not prohibited by the Convention.

8.3 The SAB recommended that the Secretariat consider the chemical families in its report and with a view toward increasing knowledge to:

---

75 "Advice from Scientific Advisory Board of the Organisation for the Prohibition of Chemical Weapons on riot control agents in connection with the Chemical Weapons Convention". C. M. Timperley, J. Forman, P. Aas, M. Abdollahi, D. Benachour, A. Al-Amri, A. Baulig, R. Becker-Arnold, V. Borrett, F. Carino, C. Curty, D. Gonzalez, M. Geist, Michael; B. Kane, Z. Kovarik, R. Martinez-Alvarez, B. Mikulak, N. Mourao, S. Neffe, E. Noguiera, P. Ramasami, Ponnadurai; S. Raza, V. Rubaylo, A. Saeed, K. Takeuchi, C. Tang, F. Trifiro, F. van Straten, A. Suarez, F. Waqar, P. Vanninen, M. Zafar-Uz-Zamen, S. Vucinic, V. Zaitsev, M. Zina, S. Holen, F. Izzati; *RSC Adv*, 2018, *8*, 41731-41739. DOI: 10.1039/c8ra08273a.

76 "Journal of Chemical Education Call for Papers: Special Issue on Chemical Security". A. W. Nelson, P. J. Hotchkiss; *J. Chem. Educ;* 2019, *96(3)*, 398-400. DOI: 10.1021/acs.jchemed.8b01041.

77 "Note by the Director-General: Request for Information from States Parties on New Types of Nerve Agents" (S/1621/2018, dated 2 May 2018): www.opcw.org/sites/default/files/documents/S_series/2018/en/s-1621-2018_e_.pdf.

78 See paragraphs 11.1 to 11.3 of the Report of the Scientific Advisory Board at its Sixteenth Session (SAB-16/1, dated 6 April 2011); www.opcw.org/sites/default/files/documents/SAB/en/sab-16-01_e_.pdf.

(a) detect such chemicals in the field, both to protect inspectors and to allow them to carry out verification or assistance activities;

(b) provide inspectors with training and equipment that will afford a high level of protection;

(c) provide inspectors and any other Secretariat staff responsible for assistance missions with appropriate training and medical countermeasures to respond to or provide advice on any potential exposure;

(d) ensure the safe handling of samples at all times, from sampling and transport to analysis and storage or destruction;

(e) have in place reference standards and data for these chemicals, as well as their precursors and degradation products, in order to establish recommended analytical methods and to enable direct comparison of measurements and spectra; and

(f) assist States Parties in strengthening their protection capabilities.

8.4 Noting that none of the information required to develop the capabilities called for in these recommendations was found in open-source or scientific literature, the SAB's report urged States Parties to share such information with the Secretariat in a manner minimising any proliferation risk.

8.5 With respect to sampling and analysis, the SAB recommended that the OPCW Laboratory and the Designated Laboratories (DLs) be prepared to analyse future samples for the possible presence of the new types of nerve agents and their analogues. The DLs and States Parties were encouraged by the SAB to contribute relevant spectra for new types of nerve agents, along with their precursors and degradation products, for inclusion in the OPCW Central Analytical Database (OCAD).

8.6 In line with the SAB's recommendations on chemicals to the Fourth Review Conference,[57] the Board recommended considering whether any changes to the Schedules of Chemicals involving new nerve agents and their precursors would be warranted in order to ensure that appropriate restrictions and monitoring are implemented.

8.7 Since the release of the report on new nerve agents, several States Parties have released information intended to aid emergency responders.[79] Additionally, scientific and open-source literature reporting the possible structures of Novichok agents continue to be published; and some of these include computational studies. Like many of the publications reviewed by the SAB in formulating its advice, these new papers generally lack experimental results or citations providing evidence and data that can

[79] (a) "Briefing note for Emergency Departments – management of suspected Novichok poisonings"; Public Health England, July 2018: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/738497/ED_briefing_note_nerve_agents.pdf. (b) "Fourth Generation Agents"; Department of Health and Human Services, United States of America, January 2019: https://chemm.nlm.nih.gov/nerveagents/FGA.htm.

be scientifically validated. In some cases, new publications provide conclusions on chemical properties that appear inconsistent with what is known about the chemical identified in Salisbury.

Subitem 8(b): Update on Schedule change proposals

8.8 Dr Forman provided an overview of the background and current status of recent submissions under paragraphs 4 and 5 of Article XV proposing the addition of new chemicals or families of chemicals to Schedule 1A of the Annex on Chemicals to the Convention.

8.9 Two submissions have been put forward. The first was a joint proposal from the United States of America, Canada, and the Netherlands recommending the addition of two families of chemicals to Schedule 1A; after evaluation by the Secretariat,[56(a)] this proposal was recommended for adoption by the Council at its Sixty-Second Meeting in January 2019.[80] The second submission came from the Russian Federation and consisted of a set of five proposals, including two groups representing single chemicals, one group containing a family of chemicals, one group containing two related chemical families, and one group containing set of 14 individual chemicals. The Russian proposals were evaluated by the Secretariat,[56(b)] but not recommended for adoption by the Council at its Sixty-Third Meeting in 25 February 2019.[81] The rejection of the Russian Federation's proposal resulted from the States Parties failing to reach a consensus on the fifth group of the Russian Federation's proposal due to disagreements on whether the chemicals contained within this proposal were consistent with the guidelines in the Convention for Schedule 1A.

8.10 The Council's decisions on both the Joint and Russian submissions were objected to on 9 April 2019.[82] These objections send both proposals to the Twenty-Fourth Session of Conference of States Parties (CSP-24, scheduled for November 2019), where they will be treated as matters of substance. Should CSP-24 adopt one or both proposals, the changes would enter into force 180 days later.

8.11 Several States Parties have suggested that the SAB review the two Article XV proposals with a view to developing a compromise proposal.[83] However, Article XV proposals can only come from States Parties.[84] There has also been discussion about potential compromise proposals or combined proposals; however, these have not been received as official proposals under Article XV.[85]

---

80 "Decision: Recommendation for a Change to Schedule 1 of the Annex on Chemicals to the Chemical Weapons Convention" (EC-M-62/DEC.1, dated 14 January 2019): www.opcw.org/sites/default/files/documents/2019/01/ecm62dec01%2B%28e%29.pdf.

81 "Draft Decision: Recommendation for a Change to Schedule 1 of the Annex on Chemicals to the Chemical Weapons Convention" (EC-M-63/DEC/CRP.1, dated 19 February 2019).

82 (a) "Russian Federation: Request for Circulation of a Document" (EC-M-62/NAT.5, dated 9 April 2019).
(b) "Burundi: Request for Circulation of a Document" (EC-M-63/NAT.4, dated 9 April 2019).

83 See for example: "Syrian Arab Republic: Request for Circulation of a Document" (EC-M-63/NAT.5, dated 16 April 2019).

84 "Circulation of Note Verbale No. NV/ODG/219226/19 Addressed to the Permanent Representation of the Syrian Arab Republic to the OPCW, Dated 2 May 2019" (EC-M-63/S/1, dated, 2 May 2019).

85 (a) "Joint Diplomatic Note 04-CA/NL/US-2019, dated 29 July 2019, from the Permanent Representations of Canada, the Netherlands, and the United States of America in Response to the Diplomatic Note from

8.12 Dr Forman also addressed the discourse around the interpretation of chemistry information (e.g. molecular structures and chemical properties) contained within the Article XV proposals. The Secretariat arranged a number of briefings to ensure that decision makers have a complete set of information to consider and understand the chemistry concepts needed for their debates, especially with regard to the presentation and description of chemicals in the Annex on Chemicals.[86] A significant component of this scientific communication has included the use of chemical structures to convey key properties and behaviour of the chemicals under consideration. This has proven to be more informative for those being introduced to chemistry than some of the complex chemical names found within the Article XV discussions.

8.13 In the discussion that followed, it was noted that with the ongoing discourse on the Annex on Chemicals, there is a great need to help decision makers more effectively comprehend chemical information. Annotating the Annex on Chemicals with chemical structures should be considered.[87]

Subitem 8(c): Computational studies on new nerve agents and sulphur mustard

8.14 Professor Ponnadurai Ramasami presented the findings of a computational study intended to shed light on molecular, electronic, spectroscopic, thermodynamic, and toxicity parameters, as well as on potential thermal and hydrolysis degradation pathways for new nerve agents.[88] Computational hydrolysis studies with these agents are also under way.

8.15 In a second presentation, Professor Ramasami presented new results from his sulphur mustard microhydration study,[89] which looked at changes in energetics, structural parameters, vibrational frequencies, and dipole moments following the addition of up to three discrete water molecules.

---

the Russian Federation dated 5 July 2019, Regarding Proposed Technical Changes to the Annex on Chemicals to the Chemical Weapons Convention" (S/1785/2019, dated 16 August 2019), (b) Note Verbale 1035 (Dated 7 June 2019) from the Permanent Representation of the Russian Federation on the Circulation of Notes Verbales 771 and 775 Regarding Proposed Technical Changes to the Annex on Chemicals to The Chemical Weapons Convention (S/1765/2019, dated 14 June 2019), (c) Joint Diplomatic Note 02-CA/NL/US-2019, Dated 3 June 2019, from the Permanent Representations of Canada, the Netherlands, and the United States of America in Response to the Diplomatic Note from the Russian Federation Dated 30 April 2019, Regarding Proposed Technical Changes to the Annex On Chemicals to the Chemical Weapons Convention (S/1758/2019, dated 3 June 2019).

86 See for example: (a) "The Expanding Chemical Universe", March 2019: www.opcw.org/sites/default/files/documents/2019/03/12%20March%202019%20EC90%20Expanding%20Chemical%20Universe.pdf. (b) The Chemical Universe Scheduled and Unscheduled", July 2019: www.opcw.org/sites/default/files/documents/2019/01/20180710-Chemical_Universe-Science_for_Diplomats_0.pdf.

87 For an informal example of how this might look, see "The Science for Diplomats Annex on Chemicals", June 2019: www.opcw.org/sites/default/files/documents/2019/06/Science_for_Diplomats_Annex_on_Chemicals_with_Functional_Group_Table.pdf.

88 H. Bhakhoa, L. Rhyman, P. Ramasami; *R. Soc. Open Sci.*; *6*, 181831 DOI: 10.1098/rsos.181831.

89 Professor Ramasami had previously discussed his work on this topic with the SAB at the Board's Twenty-Sixth Session. See paragraphs 7.5 – 7.8 of "Report of the Twenty-Sixth Session of the Scientific Advisory Board" (SAB-26/1, dated 20 October 2017): www.opcw.org/sites/default/files/documents/SAB/en/sab-26-01_e_.pdf.

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

(a) Questions on the validity of results have been raised across recently published computational studies on new types of nerve agents. The evaluation of known nerve agents for which experimental data is available to validate the computational method is recommended before drawing conclusions on the results obtained for unknown agents.

(b) Organophosphorus nerve agents with P-N bonds are expected to form adducts of acetylcholinesterase with structural analogues to tabun. The electronic and steric hindrance effects due to the phosphoramido moiety of these adducts prevents nucleophilic attack by oximes, resulting in the formation of adducts that show resistance to the classical reactivators. For these reasons, tabun, rather than sarin, might be the more appropriate choice for comparison with organophosphorus nerve agents that contain P-N bonds when considering reactivation.[90]

(c) Recent reports of the degradation of long-chain sulphur mustards[91] may be of interest for further computational microhydration studies to test the validity of models being developed against experimental data.

9. AGENDA ITEM NINE – Investigative Science

Subitem 9(a): The Investigation and Identification Team (IIT)

9.1 Mr Santiago Oñate, Coordinator of the OPCW IIT, updated the SAB on the IIT.[92] The IIT is now staffed and has started working on implementing the decision taken by States Parties to have the Secretariat put into place arrangements to identify the perpetrators of the use of chemical weapons in the Syrian Arab Republic by identifying and reporting on all information potentially relevant to the origin of chemical weapons in those instances in which the OPCW Fact-Finding Mission (FFM) in Syria determines or has determined that use or likely use occurred, and

---

90 (a) "Reversal of tabun toxicity enabled by a triazole-annulated oxime library—reactivators of acetylcholinesterase". Z. Kovarik, J. Kalisiak, N. Maček Hrvat, M. Katalinić, T. Zorbaz, S. Žunec, C. Green, Z. Radić, V. V. Fokin, K. B. Sharpless. P. Taylor; Chem. Eur. J.; 2019, 25(16), 4100-4114. DOI: 10.1002/chem.201805051. (b) "Evaluation of oxime K203 as antidote in tabun poisoning". Z. Kovarik, A. Lucić Vrdoljak, S. Berend, M. Katalinić, K. Kuča, K. Musilek, B. Radić; *Arh. Hig. Rada. Toksikol.;* 2009, *60,* 19–26. DOI: 10.2478/10004-1254-60-2009-18.

91 "Unexpected reaction pathways leading to thiodiglycol during the degradation of long-chain sulfur mustards". E. Gómez-Caballero, R. Martínez-Álvarez, M. A. Sierra; *J. Org. Chem.*; 2018, *83(20),* 12432-12439. DOI: 10.1021/acs.joc.8b01670.

92 For recent updates, see: (a) "Report by the Director-General: Progress in the Implementation of Decision C-SS-4/DEC.3 on Addressing the Threat from Chemical Weapons Use" (EC-91/DG.20, dated 1 July 2019): www.opcw.org/sites/default/files/documents/2019/07/ec91dg20%28e%29.pdf. (b) Work of the Investigation and Identification Team Established by Decision C-SS-4/DEC.3 (Dated 27 June 2018) (EC-91/S/3, dated 28 June 2019). And, (c) "Report by the Director-General: Progress in the Implementation of Decision C-SS-4/DEC.3 on Addressing the Threat from Chemical Weapons Use" (EC-90/DG.14, dated 7 March 2019): www.opcw.org/sites/default/files/documents/2019/03/ec90dg14%28e%29.pdf. For further information see: www.opcw.org/media-centre/featured-topics/decision-addressing-threat-chemical-weapons-use.

cases for which the OPCW-UN Joint Investigative Mechanism (JIM) has not issued a report.[7] The IIT consists of a coordinator, two investigators, two analysts, a senior legal adviser, a senior information systems officer, and an administrative assistant, with additional support from specialists within the Secretariat. It is a professional and independent team, working under the guidance of the OPCW Director-General.

9.2 The IIT has identified 39 incidents after examination of reports from the FFM,[93] these incidents were prioritised based on the amount of evidence gathered by the FFM, the reported number of victims, the potential to retrieve additional information, types of chemicals reported, and the availability of additional information.

9.3 Mr Oñate emphasised that in order to identify perpetrators, the IIT must consider all available information and evidence related to the original allegations of the use of chemical weapons, and must employ relevant investigative science and methodology in order to draw conclusions with a realistic degree of certainty. This includes establishing protocols for weighting and assessing evidence and information, and understanding patterns of use and behaviour. He also stressed that the IIT is not a juridical or prosecutorial body; instead, it is technical entity that will present factual information to States Parties, which will in turn define a next course of action. The IIT works independently of the States Parties and is not a replacement for national implementation, yet the results of its investigations could pave the way for further accountability. This requires that the IIT work in a way that takes into account the fact that evidence and information might be used in court at a later stage. Therefore, evidence must be of high integrity, attentive to chain-of-custody procedure, and unbiased. The IIT is expected to provide a report to States Parties in the lead-up to the Twenty-Fourth Conference of the States Parties in November 2019.

9.4 In the subsequent discussion, it was noted that the decision that produced the IIT might be viewed as a result of new challenges unforeseen at the time of the entry-into-force of the Convention, demonstrating that the Convention is a living instrument that can be adapted to changing realities. Mr Oñate noted, however, that not all States Parties share this view of the decision.

Subitem 9(b): The second and third meetings of the TWG on investigative science and technology

9.5 Dr Veronica Borrett, Chairperson of the SAB's TWG on investigative science and technology,[94] briefed the SAB on the activities of the TWG which has met twice since the Twenty-Seventh Session of the SAB. At its second meeting in November 2018, the TWG received briefings on the Secretariat's fact-finding and investigatory activities, as well as briefings from invited guests on a variety of forensic and investigative capabilities related to remote sensing and sampling, biomarker analysis,

---

93 For further information on the Fact-Finding Mission, see: www.opcw.org/fact-finding-mission.

94 The terms of reference of this TWG are available in Annex 1 of "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/sites/default/files/documents/SAB/en/sab-27-wp01_e_.pdf.

and a recent incident involving ricin.[95] In April 2019, at its Third Meeting, the TWG received briefings on the Secretariat's non-routine activities from current and former chemical weapons inspectors, as well as briefings from invited guests with experience in forensic science, international treaty verification, the collection of evidence and information under adverse circumstances, unmanned systems, and the use of open-source information for verification applications.[96]

9.6 Through briefings, discussions and sub-group activities, the TWG, has collected important background information for its consideration of the needs of the Secretariat, as well as equipment and procedures that could help strengthen the Secretariat's capabilities.

9.7 The TWG is of the view that when undertaking investigative activities, OPCW inspection teams could benefit from having a "forensic adviser" within the team or available to advise from off-site, for planning and conduct of investigative activities to help ensure that they meet international forensic standards, take advantage of modern forensic methods, and tap into the broad range of forensic expertise that is available. Furthermore, establishing working relationships in advance with forensic science organisations, laboratories, and experts is important to ensure that the Secretariat has a network that can provide advice and laboratory support at short notice.

9.8 After reviewing the reports of the TWG from its first, second and third meetings, the SAB submits the following recommendations to the Director-General:

(a) It is recommended that a forensic adviser with broad experience in forensic science and international law should be considered to provide advice to the Director-General and the OPCW. An independent external expert could be considered.

(b) It is recommended that the Secretariat should ensure that forensic issues are included in standard operating procedures (SOPs) or working instructions, including those related to on-site sample collection, handling, curation and storage, and annotation, in accordance with forensic best practices.

(c) It is recommended that relevant OPCW staff should receive training on forensic processes, procedures, and techniques relevant to their role.

(d) It is recommended that scenarios developed for mission planning and training should be adapted for the purpose of evaluating sampling and detection systems to meet mission conditions.

9.9 Dr Borrett had also briefed States Parties on the work of the TWG in margins of the Fourth Review Conference,[31(b)] and described the need for such advisory groups in a

---

95 "Summary of the Second Meeting of the Scientific Advisory Board's Temporary Working Group on Investigative Science and Technology" (SAB-28/WP.2, dated 21 January 2019): www.opcw.org/sites/default/files/documents/2019/01/sab28wp02%28e%29.pdf.

96 "Summary of the Third Meeting of the Scientific Advisory Board's Temporary Working Group on Investigative Science and Technology" (SAB-28/WP.3, dated 4 June 2019): www.opcw.org/sites/default/files/documents/2019/06/sab-28-wp03%28e%29.pdf.

lecture presented at the Australian and New Zealand Forensic Science Society (ANZFSS) Twenty-Fourth International Symposium on the Forensic Sciences.[97] The TWG will meet for its Fourth and Fifth Meetings in September and November 2019 respectively. It intends to produce a substantive report, including further recommendations that would be finalised before the Group's mandate ends in February 2020.

Subitem 9(c): Scenario-based planning for non-routine missions

9.10 Dr Michael Hoefer (Head, Inspectorate Capacity Building and Contingency Operations Cell) discussed the use of scenario-based planning and training for non-routine missions. He noted that starting from 2013, with the confirmation of the use of chemical weapons in the Syrian Arab Republic[98] and Syria's accession to the Convention,[99] the Secretariat's portfolio of non-routine missions has continued to expand.[51a] These non-routine missions now include the FFM,[93] technical assistance,[8,100,101,102] inspections at the Syrian Scientific Studies and Research Centre (SSRC),[103] the Declarations Assessment Team (DAT),[104] and the Rapid Response and Assistance Mission (RRAM).[105] The IIT brings an additional mandate to factor into

---

97 A plenary presentation delivered by the Chairperson of the TWG on Investigative Science and Technology was published in the scientific literature: "Investigative Science and Technology Supporting the Organisation for the Prohibition of Chemical Weapons (OPCW)". V. Borrett, C. M. Timperley, J. E. Forman, C. Tang; *Australian Journal of Forensic Science*, 2018, DOI: 10.1080/00450618.2018.1559356.

98 "United Nations Mission to Investigate Allegations of the Use of Chemical Weapons in the Syrian Arab Republic" (UNSC, A/68/663-S/2013/735, dated 13 December 2013): https://undocs.org/A/68/663.

99 Information related to activities of OPCW in the Syrian Arab Republic is available at www.opcw.org/media-centre/featured-topics/syria-and-opcw.

100 "Note by the Technical Secretariat: Summary of the Report on Activities Carried Out in Support of a Request for Technical Assistance by the United Kingdom of Great Britain and Northern Ireland (Technical Assistance Visit TAV/02/18)" (S/1612/2018, dated 12 April 2018); www.opcw.org/sites/default/files/documents/S_series/2018/en/s-1612-2018_e___1_.pdf.

101 See paragraph 1.10 of "Report of the OPCW on the Implementation of the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction in 2016" (C-22/4, dated 29 November 2017): www.opcw.org/sites/default/files/documents/CSP/C-22/en/c2204_e_.pdf.

102 For a recent deployment of a team to provide technical assistance and evaluation to the Syrian Arab Republic, see "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, 2 March 2018).

103 (a) "Status of Implementation of Executive Council Decision EC-83/DEC.5 (dated 11 November 2016)" (EC-87/DG.15, dated 23 February 2018; and EC-87/DG.15/Add.1, dated 28 February 2018), (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), and (c) "Report by the Director-General: 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/sites/default/files/documents/EC/84/en/ec84dg25_e_.pdf.

104 For further information on the Declaration Assessment Team, see: www.opcw.org/declaration-assessment-team

105 (a) "Note by the Technical Secretariat: Establishment of a Rapid Response Assistance Team" (S/1381/2016, dated 10 May 2016): www.opcw.org/sites/default/files/documents/S_series/2016/en/s-1381-2016_e_.pdf and, (b) "Note by the Technical Secretariat: Guidelines for States Parties Requesting a Rapid Response and Assistance Mission" (S/1429/2016, dated 17 October 2016): www.opcw.org/sites/default/files/documents/S_series/2016/en/s-1429-2016_e_.pdf.

current and future missions and modalities. Furthermore, these missions have demonstrated that scenarios previously thought unlikely could in fact take place given certain circumstances. In this regard, he emphasised the need for the Secretariat to be prepared to respond to new types of missions that may take place in unfamiliar operating environments.

9.11 Dr Hoefer outlined two key aspects that will help define the response capacity that the Secretariat needs in terms of people, equipment, and systems, particularly as each type of mission requires a range of capacities to be successful. First, having a more realistic view of the types of scenarios involving chemical weapons that may trigger a non-routine OPCW mission, and second, institutionalising structured operational planning processes within the Secretariat for a number of such archetypical scenarios. While the second aspect is relatively straightforward to address through training, identifying future possible scenarios is not.

9.12 The objectives of using a scenario-based approach are to improve the Secretariat's response capabilities, address gaps through staff recruitment and training—as well as through external partnership arrangements—and establish operational plans that are flexible enough to be adjusted for a real mission. External partnerships are also beneficial, and could be strengthened through a possible accreditation system for national CBRN-response teams, by considering arrangements with international and regional organisations, as well as through continued participation in United Nations-based inter-agency projects (e.g. inter-agency interoperability in response to terrorist attacks using chemical or biological weapons), and with liaisons in key locations in New York, Geneva, and Vienna.

9.13 The SAB's views were solicited on whether academia, think tanks, or other scientific and technical entities, have tools, methods, or techniques that could help identify future trends and scenarios relevant to the OPCW.

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

(a) A variety of scenarios can be envisioned in resource-limited or non-permissive settings, in States with highly divergent CBRN response capabilities, and in response to a broad variety of chemical or other CBRN materials.

(b) A discussion of scenarios developed by the Secretariat is scheduled for the upcoming fourth meeting of the TWG on investigative science in September 2019. SAB and TWG members will be encouraged to formulate questions and provide views on the scenarios, with the objective of providing advice on the types of scientific and technological tools and methods that might allow inspectors to overcome situational constraints on their capabilities.

10. AGENDA ITEM TEN – Legacy chemical weapons

Subitem 10(a): Utilising hyperaccumulators to clean up contaminated soil

10.1 Dr Mei Lei (guest speaker, Chinese Academy of Science) provided the Board with an overview of the use of phytoextraction to remediate arsenic-enriched soil,[106] with a focus on soil that had been contaminated by abandoned chemical weapons containing arsenic. Dr Lei further explained that metal-accumulating plants, referred to as hyperaccumulators, can be used to remove metals from soil through concentrating contaminants into harvestable vegetation.[107]

10.2 Dr Lei presented data from pilot scale and field studies of the use of *Pteris vittata* as an arsenic accumulating plant.[108] This included a discussion on the use in remediating arsenic contaminated soil, arsenic-removal efficiency (which can be increased using oxidizers and arsenic mobilisers[109]), associated costs, and other limitations.

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

(a) The availability of suitable plants for humid and dry environments for phytoremediation was discussed, in very arid environments, suitable fast-growing vegetation that can be frequently harvested may not be available.

(b) The enhancement of metal uptake might be achieved through the alteration of a plants microbiome.

(c) The work presented on arsenic hyperaccumulators was seen as a reminder of the importance of assessing the environmental impact of toxic waste, and

---

106 "Intercropped *Pteris vittata* L. and *Morus alba* L. presents a safe utilization mode for arsenic-contaminated soil". X. Wan, M. Lei, T. Chen, J. Yang; *Science of the Total Environment*, 2017, 1467-1475. DOI: 10.1016/j.scitotenv.2016.11.148.

107 (a) "Hyperaccumulator Plants from China: A Synthesis of the Current State of Knowledge". J. Li, H. Gurajala, L. Wu, A. Ent, R. Qiu, A. Baker, Y. Tang, X. Yang, W. Shu; *Environmental Science & Technology*, 2018, *51(21)*. DOI: 10.1021/acs.est.8b01060. (b) "Accumulation of As, Cd and Pb in Sixteen Wheat Cultivars Grown in Contaminated Soils and Associated Health Risk Assessment". G. Guo, M. Lei, Y. Wang, B. Song, J. Yang; *International Journal of Environmental Research and Public Health*, 2018, *15(11)*. DOI: 10.3390/ijerph15112601. (c) "Speciation and uptake of antimony and arsenic by two populations of *Pteris vittata* L. and *Holcus lanatus* L. from co-contaminated soil". X. Wan, J. Yang, M. Lei; *Environmental Science and Pollution Research*, 2018, volume 25 (32), 32447-32457. DOI: 10.1007/s11356-018-3228-z.

108 (a) "Reaction mechanism of arsenic capture by a calcium-based sorbent during the combustion of arsenic-contaminated biomass: A pilot-scale experience". M. Lei, Z. Dong, Y. Jiang, P. Longhurst, X. Wan, G. Zhoul; *Frontiers of Environmental Science & Engineering*, 2019, 13(24). DOI: 10.1007/s11783-019-1110-y. (b) "Phytoextraction of arsenic-contaminated soil with *Pteris vittata* in Henan Province, China: comprehensive evaluation of remediation efficiency correcting for atmospheric depositions". M. Lei, X. Wan, G. Guo, J. Yang, T. Chen; *Environmental Science and Pollution Research*, 2018, *25(1)*, 124-131. DOI: 10.1007/s11356-016-8184-x. (c) (b) "Application of arsenic hyperaccumulator *Pteris vittata L.* to contaminated soil in Northern China". Y. Zhang, X. Wan, M. Lei; *Journal of Geochemical Exploration*, 2017, *182(B)*, 132-137. DOI: 10.1016/j.gexplo.2016.07.025.

109 "Comparison among soil additives for enhancing *Pteris vittata* L.: Phytoremediation of As-contaminated soil". J. Yang, S. Yang, M. Lei, J. Yang, X. Wan, T. Chen, X. Wang, G. Guo, J. Guo, S. Liu; *International Journal of Phytoremediation*, 2018, *20(13)*, 1300-1306. DOI: 10.1080/15226514.2017.1319325.

identifying best practices for the clean-up of contaminated soil. Developments in environmentally friendly remediation approaches for chemically contaminated sites could be a topic of interest for the SAB's scientific review.

(d) The uptake of specific chemical markers in plants can also provide an indication of chemical agent exposure or environmental presence. In this regard, plants that can accumulate chemical markers of nerve agent exposure have been reported.[67,110]

Subitem 10(b): Information systems on legacy chemical munitions

10.4 Professor and Dr Bartłomiej Pączek (guest speaker and Captain in the Polish Naval Academy) briefed the SAB on an information platform on sea-dumped chemical weapons that has been developed through international projects around the Baltic Sea.[111] This system contains information collected in studies of munition conditions, leakage, environmental contamination, and impact on sea flora and fauna. The system is an artificial intelligence supported tool that utilises biochemical knowledge for risk assessments in relation to shipping, animal life, infrastructure (such as windfarms or underwater cables), and tourist activity.

10.5 The system includes a catalogue of pre-1946 munitions that were dumped in the Baltic,[112] an Interactive GIS system,[113] a repository of historical documents (including maps), chemical and physical measurements, oceanographic data, and a decision support system. With continued monitoring of the dump sites and scattered munitions along transport routes used by the ships that carried the weapons, the information continues to be updated. E-learning tools and reference books that can be carried on fishing boats are also being developed.

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

(a) Environmental contamination and risk of exposure from leaking chemical containers is related to the immediate environment of the dump site. When containers and munitions are covered under sediment, the anaerobic environment can slow down or prevent corrosion and subsequent leakage.

(b) The correlation of the artificial intelligence risk assessment to real incidents is not available, as very few incidents have occurred, and available data to draw upon is limited. The information provided by the system is intended to be used for assessing risk under specific scenarios and situations related to the

---

110 "Nerve agent markers screening after accumulation in garden cress (*Lepidium sativum*) used as a model plant object". B. Sarvina, M. Himmelsbach, T. Baygildiev, O. Shpigun, I. Rodin, A. Stavrianidi, W. Buchberger; *J. Chrom. A*; 2019, *597*, 214-219. DOI: 10.1016/j.chroma.2019.04.025.

111 These include projects such as (a) CHEMSEA - Chemical Munitions Search & Assessment (which ran from 2007 – 2013): http://eu.baltic.net/Project_Database.5308.html?contentid=69&contentaction=single. (b) DAIMON (Decision Aid for Marine Munitions): https://www.daimonproject.com/. And, (c) HELCOM Baltic Sea Action Plan: http://www.helcom.fi/baltic-sea-action-plan.

112 On-line munition catalog: http://dss.amw.gdynia.pl/catalog.

113 Geographic information systems: (a) http://dss.amw.gdynia.pl/chemsea and (b) http://dss.amw.gdynia.pl/daimon.

potential of coming into contact with sea-dumped munitions and possibly contaminated environments.

(c) The environmental fate and impact assessment of toxic wastes resulting from chemical weapons, storage, release, and disposal was noted as an area of interest for the Secretariat. Information platforms like the one presented by Professor Pączek are valuable resources that can help inform risk assessments in areas of potential contamination from toxic waste.

11. AGENDA ITEM ELEVEN – Scientific and technological elements of verification technologies, emerging technologies, and new equipment

Subitem 11(a): Artificial intelligence (AI) for chemical verification

11.1 Dr Eric Tan Lee Han (guest speaker, DSO National Laboratories, Singapore) briefed the SAB on the use of AI to overcome the bottleneck of chemical structure elucidation in analytical chemistry. The problem of identifying an unknown chemical given its mass spectrum and its chemical formula—a task that might take well trained chemists several days to complete—can be addressed using data-driven approaches. Given a chemical formula, there could be over a million possible candidate structures. These structures can be ranked using neural networks to predict the presence of substructures based on the mass spectrum, and these substructures match with the candidate structures. Empirically, this approach can be validated on a data set of chemical agents built for unknown chemical identification. The DSO substructure classifiers can attain a micro F1-scores over 90%,[114] and can find the correct structures among the top 5 candidates in 81.1% and 79.2% of test cases for phosphonate and phosphonothiolate compound classes.[115]

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

(a) A bottleneck in the workflow was found with commercially available software used to generate possible chemical structures. Tools that allow for the generation of complex molecular structures with a variety of types of atoms are needed and may require customisation.

(b) The current method was developed with the two classes of chemical agents described by Dr Lee with promising results. Further development and addition of new classes of chemicals is ongoing.

---

[114] F1 score = measure of accuracy of classifier in predicting the likelihood of each substructure existing in the test case mass spectrum, by taking into consideration true positives (TP), false positives (FP), and false negatives (FN) when compared to the ground truth structure.

[115] (a) “Chemical Structure Elucidation from Mass Spectrometry by Matching Substructures”. J. Lim, J. Wong, M. X. Wong, L. H. E. Tan, H. L. Chieu, D. Choo, N. K. N. Neo; 2018, arXiv:1811.07886 [physics.chem-ph]. (b) "Chemical Structure Elucidation from Mass Spectrometry by Matching Substructures". J. Lim, J. Wong, M. X. Wong, L. H. E. Tan, H. L. Chieu, D. Choo and N. K. N. Neo, in *2nd NIPS Workshop on Machine Learning for Molecules and Materials (MLMM)*, Montreal Canada, 2018: https://www.groundai.com/project/chemical-structure-elucidation-from-mass-spectrometry-by-matching-substructures/.

Subitem 11(b): Established and novel sulphur mustard adducts of human serum albumin for verification of poisoning

11.3 Mr Markus Siegert (guest speaker, Bundeswehr Institute of Pharmacology and Toxicology in Munich, and Humboldt-Universität zu Berlin, Germany) briefed the SAB on his work in studying sulphur mustard adducts. Sulphur mustard is a vesicant, and exposure leads to temporary blindness, erythema and blistering with complicated and delayed wound healing in a dose-dependent manner. Despite the fact that its production, stockpiling, and use is prohibited by the Convention, sulphur mustard still represents a serious threat to civilians and military forces as evidenced by recent incidents in the Middle East.[116] Accordingly, reliable bioanalytical methods for the verification of exposure to sulphur mustard are required to support the work of the OPCW.

11.4 Mr Siegert presented a compilation of diverse methods of the forensic analysis of plasma samples to identify sulphur mustard poisoning by peptide biomarkers.[117] Samples were proteolysed using pronase, proteinase K, and pepsin separately to generate different human serum albumin- (HSA-) derived biomarkers: HETE-C^{34}P, HETE-C^{34}PF, LQQC^{34}(-HETE)PFEDHVKL, and AE^{230}(-HETE)VSKL. HETE represents the hydroxyethylthioethyl-moiety which is typical for sulphur mustard -derived protein adducts. These methods were successfully applied to biomedical samples from human victims exposed to sulphur mustard in the Middle East in 2015.[116(a)]

11.5 In addition, Mr Siegert introduced a novel target of sulphur mustard in HSA, Met^{329},[118] After proteolysis of sulphur mustard -incubated HSA or human serum using pepsin, the alkylated tetrapeptide LGM^{329}(-HETE)F was identified. Alkylation of the sulphur atom of the Met side chain resulted in a permanently positively charged methionyl sulfonium ion. This novel analyte was compared with the established biomarkers HETE-CP and HETE CPF in terms of sensitivity. It was found that LGM(-HETE)F has only a slightly higher limit of identification (32.2 nM) than HETE-CP and HETE-CPF (both 15.6 nM). However, LGM(-HETE)F exhibited a limited in vitro stability of five days and might therefore be a beneficial short-term biomarker. Furthermore, a transfer of the HETE-moiety from the methionyl sulfonium ion to other nucleophilic sidechains in HSA such as the Cys^{34} residue as well as Glu residues was observed.

---

116 (a) "Forensic evidence of sulfur mustard exposure in real cases of human poisoning by detection of diverse albumin-derived protein adducts". H. John, M. Koller, F. Worek, H. Thiermann, M. Siegert; *Archives of Toxicology*, 2019. DOI: 10.1007/s00204-019-02461-2. (b) "Victims of chemical terrorism, a family of four who were exposed to sulfur mustard" S. Sezigen, K. Ivelik, M. Ortatatli, M. Almacioglu, M. Demirkasimoglu, R. K. Eyison, Z .I. Kunak, L. Kenar; *Toxicology Letters;* 2019, *303*, 9-15. DOI: 10.1016/j.toxlet.2018.12.006. (c) "Acute intensive care unit management of mustard gas victims: the Turkish experience". E. Kilic, M. Ortatatli, S. Sezigen, R. K. Eyiso, L. Kenar; *Cutaneous and Ocular Toxicology*; 2018, *37(4)*, 332-337. DOI: 10.1080/15569527.2018.1464018.

117 "Optimized verification method for detection of an albumin-sulfur mustard adduct at Cys^{34} using a hybrid quadrupole time-of-flight tandem mass spectrometer after direct plasma proteolysis". H. John, M. Siegert, F. Gandor, M. Gawlik, A. Kranawetvogl, K. Karaghiosoff, H. Thiermann; *Toxicology Letters*, 2016, *244*, 103-111. DOI: 10.1016/j.toxlet.2015.09.027.

118 "Methionine^{329} in human serum albumin: A novel target for alkylation by sulfur mustard". M. Siegert, F. Gandor, A. Kranawetvogl, H. Borner, H. Thiermann, H. John; *Drug Testing and Analysis*, 2019, *11(5)*, 659-668. DOI: 10.1002/dta.2548.

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

(a) In vitro stability studies of Met[329] and Cys[34] adducts may have the potential to provide estimates of the time since exposure occurred. The samples tested however, were not able to provide such information as they contained no detectable Met[329] adducts due to their age.

(b) The clinical presentation of exposure that was shown in the briefing had distinct features in addition to those typical for exposure to sulphur mustard. In this regard, it was noted that the sulphur mustard analysed from incidents in 2015 was Levinstein mustard and highly impure.[119]

(c) The potential for observing chemical weapon agent adducts formed by exposure to impure agents may have some utility in recognising the signatures of a synthesis route.

Subitem 11(c): Protein adductomics: methodologies for the untargeted screening of adducts to serum albumin and haemoglobin in human blood samples

11.7 Dr Henrik Carlsson (guest speaker, Uppsala University, Sweden) briefed the SAB on measurements of reaction products of electrophiles as adducts to the abundant proteins haemoglobin (Hb) and HSA in human blood samples. Over the last decade, methods for untargeted adduct screening (adductomics[120]) have used liquid chromatography-mass spectrometry to detect large numbers of previously unknown Hb and HSA adducts. Dr Carlsson described methods that have been applied to Hb

---

119 (a) See paragraphs 9.17 to 9.18 of "Report of the Twenty-Fifth Session of the Scientific Advisory Board" (SAB-25/1*, dated 31 March 2017): www.opcw.org/sites/default/files/documents/SAB/en/sab2501_e_.pdf. (b) "Note by the Technical Secretariat: Report of the OPCW Fact-Finding Mission in Syria Regarding Alleged Incidents in Marea, Syrian Arab Republic, August 2015" (S/1320/2015, dated 29 October 2015): https://www.opcw.org/sites/default/files/documents/2018/11/s-1320-2015_e_.pdf.

120 (a) "Protein adductomics: A comprehensive analysis of protein modifications by electrophiles". T. Shibata, K. Uchida; *Free Radical Biology and Medicine*, 2019. DOI: 10.1016/j.freeradbiomed.2019.02.034. (b) "Discovery of Noven N-(Hydroxybenzyl)valine Hemoglobin Adducts in Human Blood". A. Degner, H. Carlsson, I. Karlsson, J. Eriksson, S. Pujari, N. Tretyakova, M. Tornqvist;", *Chemical Research in Toxicology*, 2018, *31(12)*, 1305-1314. DOI: 10.1021/acs.chemrestox.8b00173. (c) "Strategy for identifying unknown haemoglobin adducts using adductome LC-MS/MS data: Identification of adducts corresponding to acrylic acid, glyoxal, methylglyoxal, and 1-octen-3-one". H. Carlsson, M. Tronqvist; *Food and Chemical Toxicology*; 2016, *92*, 94-103. DOI: 10.1016/j.fct.2016.03.028. (d) "Adductomics Pipeline for Untargeted Analysis of Modifications to Cys[34] of Human Serum Albumin". H. Grigoryan, W. Edmands, S. Lu, Y. Yano, L. Regazzoni, A. Lavarone, E. Williams, S. Rappaport; *Anal. Chem.*; 2016, *88(21)*, 10504-10512. DOI: 10.1021/acs.analchem.6b02553. (e) "LC-MS/MS Screening Strategy for Unkown Adducts to N-Terminal Valine in Hemoglobin Applied to Smokers and Nonsmokers". H. Carlsson, H. Stedingk, U. Nilsson, M. Tornqvist; *Chemical Research in Toxicology*, 2014, *27(12)*, 2062-2070. DOI: 10.1021/tx5002749. (f) "Profiling cys[34] adducts of human serum albumin by fixed-step selected reaction monitoring". H. Li, H. Grigoryan, W. Funk, S. Lu, S. Rose, E. Williams, S. Rappaport; *American Society for Biochemistry and Molecular Biology*, 2011, *10(3)*. DOI: 10.1074/mcp.M110.004606. (g) Adductomics: Characterizing exposures to reactive electrophiles". S. Rappaport, H. Li, H. Grigoryan, W. Funk, E. Williams; *Toxicology Letters*, 2010, *213(1)*, 83-90. DOI: 10.1016/j.toxlet.2011.04.002.

and HSA adductomics.[121] Critical methodological aspects regarding the choice of target protein, sample preparation, mass spectrometry, data evaluation, and strategies for identification of detected unknown adducts were discussed.

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

(a) Haemoglobin has a 120 day half-life in blood, while HSA has a 20-day half-life. The higher the abundance of a protein and the longer its half-life, the more suitable it will be for adductomics studies.

(b) The approaches presented were recognised as being valuable for the work of the DLs,[122] particularly for the identification of the large diversity of possible nerve agent structures resulting from variable alkyl chains.

(c) Researchers in the field are working on improvements in sample preparation and instrumentation. Other areas of interest for optimisation include simplified evaluation, improved quantification, and the inclusion of several nucleophilic sites for assessment.

12. AGENDA ITEM TWELVE – Assistance and protection

Subitem 12(a): Evidence-based decontamination strategies for responding to chemical incidents

12.1 Professor Robert Chilcott (guest speaker, University of Hertfordshire, United Kingdom) presented the salient features of new United States Federal guidance ("PRISM") for responding to a mass casualty chemical incident.[123] The PRISM guidance was funded by the United States Biomedical Advanced Research and Development Authority (BARDA) and is based on a comprehensive, six-year programme of laboratory studies, clinical research, and field trials that underpin various aspects of the new response process. Pertinent data supporting key components of the PRISM incident response were described.

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

(a) In following the PRISM guidelines, dry decontamination procedures (followed by showering) were observed to be generally more effective, except when the

---

121 "Protein adductomics: methodologies for untargeted screening of adducts to serum albumin and haemoglobin in human blood samples". H. Carlsson, S. Rappaport, M. Tornqvist; *High-Throughput*, 2019, *8(1)*, 6. DOI: 10.3390/ht8010006.

122 "Adductomics: a promising tool for the verification of chemical warfare agents' exposures in biological samples". R. Golime, B. Chandra, M. Palit, D. Dubey; *Archives of Toxicology*, 2019. DOI: 10.1007/s00204-019-02435-4.

123 (a) Decontamination Guidance for Chemical Incidents: https://www.medicalcountermeasures.gov/barda/cbrn/prism/ (b) "Evaluation of US Federal Guidelines (Primary Response Incident Scene Management [PRISM]) for Mass Decontamination of Casualties During the Initial Operational Response to a Chemical Incident". R. Chilcott, J. Larner, A. Durrant, P. Hughes, D. Mahalingam, S. Rivers, E. Thomas, N. Amer, M. Barrett, H. Matar, A. Pinhal, T. Jackson, K. Barnett, J. Reppucci; *Annals of Emergency Medicine*, 2019, *73(6)*, 671-684. DOI: 10.1016/j.annemergmed.2018.06.042.

contaminant is a powder. However, it was noted that in resource-limited settings, dry wipes may not be readily available. Data on the use of dry absorbent materials (such as sand or clay-based soils) could be valuable for developing alternative dry decontamination procedures.

(b) Hair remains a problem for decontamination of lipophilic materials; in such cases of exposure, removal of hair may be necessary.[124]

(c) The integration of triage with decontamination procedures for large-scale incidents was identified as critical for overall response effectiveness.

(d) A decision aiding tool developed by experts in medicine and emergency response to help identify the need for patients exposed to chemical agents to undertake wet decontamination is currently available for PRISM.[125] "The development of guidebooks, decision aiding tools and apps that can provide quick access to information on decontamination protocols and best practices was recognised as highly valuable for emergency responders.

Subitem 12(b): OPCW Symposium on Medical Treatment of Chemical Warfare Victims

12.3 Dr Shahriar Khateri (OPCW Assistance and Protection Branch) informed the SAB on the "International Symposium on Medical Treatment of Chemical Warfare Victims: Challenges and Hopes" which was organised by the OPCW in The Hague from 28 to 29 June 2018[126] as a follow-up activity to a decision taken by the Sixteenth Conference of the States Parties in 2011[127] on the establishment of an international support network for victims of chemical weapons. The objective of the Symposium was to consider how the OPCW Technical Secretariat, together with interested States Parties, other relevant international organisations, and the international medical community could most usefully provide medical support to victims of chemical weapons.[128,129]

12.4 The symposium was intended to promote international scientific collaboration to fill gaps in knowledge and treatment in the field, as a means of improving outcomes for

---

124 Decontamination and management of contaminated hair following a CBRN or HazMat incident. H. Matar, A. Pinhal, N. Amer, M. Barrett, E. Thomas, P. Hughes, J. Larner, R. P Chilcott; *Toxicol Sci.*; 2019. DOI: 10.1093/toxsci/kfz145 (epublication ahead of print).

125 ASPIRE (Algorithm Suggesting Proportionate Incident Response Engagement): https://chemm.nlm.nih.gov/aspire.htm.

126 Symposium on Medical Treatment of Victims of Chemical Weapons: Challenges and Hopes, OPCW News Item, 2 July 2018: www.opcw.org/media-centre/news/2018/07/symposium-medical-treatment-victims-chemical-weapons-challenges-and-hopes.

127 "Decision: the Establishment of The International Support Network for Victims of Chemical Weapons and the Establishment of a Voluntary Trust Fund for This Purpose" (C-16/DEC.13, dated 2 December 2011): www.opcw.org/sites/default/files/documents/CSP/C-16/en/c16dec13_e_.pdf.

128 Medical Aspects of Assistance and Protection against Chemical Weapons: www.opcw.org/resources/assistance-and-protection/medical-aspects-assistance-and-protection-against-chemical.

129 Supporting Victims of Chemical Weapons: www.opcw.org/our-work/supporting-victims-chemical-weapons.

victims of chemical weapons. To this end, symposium participants developed a declaration with recommendations for the way forward.[130]

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

(a) The SAB received copies of the updated edition of the OPCWs "Practical Guide for Medical Management of Chemical Warfare Casualties".[131] Dr Khateri indicated that a project to produce a second volume addressing long-term care and health impacts was being discussed.

(b) There is a paucity of information on the prognosis and treatment of chronic aspects and complications of exposure to chemical weapons. The publication of a book about late complications of and treatments for exposure to chemical weapons would help fill a significant information gap. Dr Ghanei has conducted literature reviews, identified suitable experts, and has clinical experience in this area.[132] A presentation at the next session of the SAB is planned.

(c) The late effects in and medical management of victims of chemical warfare agent exposure as they age might be further considered for an international workshop or a working group to capture and publish relevant information.

Subitem 12(c): Chemical incident preparedness for hospitals (HOSPREP)

12.6 Mr Guy Valente (OPCW Assistance and Protection Branch) and Mr Sebastian Simonsen (OPCW Inspectorate) briefed the SAB on the chemical incident preparedness for hospitals (HOSPREP) project. This is an incident preparedness project to ensure that a hospital is able to remain operational in the face of a chemical event. The training and scenarios discussed were informed by the sarin incidents in Tokyo in the 1990s. During the presentation, a model of a decontamination shower system designed to be assembled from easily available materials and suitable for resource-limited settings was demonstrated. The Assistance and Protection Branch is developing instructions and training materials on this concept.

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

(a) Several questions were raised on water consumption and isolation of contaminated water when using this kind of design-it-yourself (DIY)

---

130 Symposium on Medical Treatment of Victims of Chemical Weapons: Challenges and Hopes, Symposium Declaration: www.opcw.org/sites/default/files/documents/2019/03/OPCW_Medical_Symposium_Declaration.pdf.

131 Practical Guide for Medical Management of Chemical Warfare Casualties, Organisations for the Prohibition of Chemical Weapons, 2019: www.opcw.org/resources/assistance-and-protection/practical-guide-medical-management-chemical-warfare-casualties.

132 A. Ahmadi, J. Salimian, M. Ghanei, S. Azimzadeh, "Mustard-DB: a database for molecular, cellular, and clinical signatures of Mustard Gas complications"; 2019. Chemical Injuries Research Center, Systems Biology and Poisonings Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran; http://mustard-db.com/.

decontamination shower system. Such considerations would need to be specific to the circumstances in which the system is deployed.

(b) The SAB supports and encourages innovative and DIY approaches to capacity building in potentially resource-limited settings that the Assistance and Protection Branch is exploring. The Board recognises great value in DIY approaches in yielding fieldable solutions with assistance and protection, as well as chemical safety and security relevance.

(c) Following the DIY spirit, the Secretariat would be well suited to share useful information that could be provided by stakeholders engaged in assistance and protection and chemical safety and security-related DIY projects. Such DIY projects might also provide a useful basis for funded research projects through the capacity-building programmes.

13. AGENDA ITEM THIRTEEN – Digitalisation

Subitem 13(a): Digital transformation powered by AI and related cybersecurity considerations

13.1 Mr Maciej Surowiec (guest speaker, Microsoft, Inc.) spoke to the SAB about AI powered digital transformation that is being adopted across industries and sectors. Examples discussed included mosquito trapping and monitoring,[133] medical disease applications,[134] genomics, and self-driving vehicles.[135] The use of AI as a means to augment human capability is not new, however current AI capabilities have seen profound improvement due to increasingly powerful algorithms, the availability of greater amounts of computational power, and access to extremely large amounts of data for mining and algorithm training.[136] Algorithms can be trained by letting them try and fail continually in a given task. The failure modes are identified and avoided as the AI becomes more proficient. To avoid real-world accidents, training can be provided in virtual environments; Mr Surowiec provided a self-driving car as an example. The car can be trained virtually to recognise and avoid objects, before allowing it to drive down an actual street.

13.2 Turning to policy issues, Mr Surowiec discussed the EU Commission initiatives[137] for use of AI and emerging ethical challenges. He then introduced principles adopted by Microsoft related to the ethics of AI: fairness (to ensure algorithms don't have bias); reliability and safety (testing for effectiveness in non-ideal circumstances); privacy

---

133 Building a better mosquito trap: How a Microsoft research project could help track Zika's spread: https://news.microsoft.com/features/building-a-better-mosquito-trap-how-a-microsoft-research-project-could-help-track-zikas-spread/#sm.000006ip5r949vdw2rexdyfudjj3x.

134 "High-performance medicine: the convergence of human and artificial intelligence". E. J. Topol; *Nature Med.*; 2019, *25*, 44–56. DOI: 10.1038/s41591-018-0300-7.

135 "Self-driving cars take the wheel", MIT Technology Review, 15 February 2019: https://www.technologyreview.com/s/612754/self-driving-cars-take-the-wheel/.

136 For information on the status of the field, see: "2018 AI Index Report", Artificial Intelligence Index: http://cdn.aiindex.org/2018/AI%20Index%202018%20Annual%20Report.pdf.

137 Communication Artificial Intelligence for Europe, European Commission: https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

and security, and inclusiveness (ensuring there is no digital divide). All four of these factors are underpinned by the principles of transparency and accountability.

13.3 AI has also enabled criminal activity in a decentralised manner. Mr Surowiec described the associated challenges as much more complex than simply organised cybercrime—cyberattacks against States and commercial entities occur with high frequency (especially attacks against cloud server systems). Such attacks might be considered as occurring at a threshold just below that of armed conflict. Key vectors of such attacks are spear-phishing, identity theft, and insider threat. The unprecedented amount of data allows algorithms to be trained to identify unusual cyber events. However, the signatures are dynamic and cyber security must continually adapt to new challenges. Microsoft has actually proposed a Digital Geneva Convention to protect cyberspace,[138] and modalities of nuclear forensic analysis used at the IAEA have informed approaches for cyber forensics. Challenges and questions continue to emerge in regard to AI. For example, how can lines be drawn on legal compliance in cyberspace? A frequent question concerns the responsibility of ensuring that AI technology development has a positive impact: is that the responsibility that of a State or an AI developer? Mr Surowiec noted that while regulation is the domain of governments, companies do have responsibility to ensure compliance issues are understood and addressed.

13.4 Mr Surowiec concluded by describing three new developments that are receiving attention: the deployment of data centres on the ocean floor (which has raised issues of international jurisdiction depending on where in the ocean it is located),[139] the use of DNA as a high-density data storage medium (which has been demonstrated in proof of concept studies),[140] and the development of quantum computers[141] (which may pose challenges for current data encryption and protection methods).

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

(a) Artificial intelligence is an enabler for many capabilities; the availability of codes and shared resources for innovation[142] fuel advances and new milestones.

(b) The AI industry is often viewed as making decisions in a way that is opaque to regulatory authorities. However, as policy needs are addressed within the development of applied AI tools, regulatory agencies do become more involved and aware (automobile safety requirements in autonomous vehicles

---

138 A Digital Geneva Convention to protect cyberspace, Microsoft: https://www.microsoft.com/en-us/cybersecurity/content-hub/a-digital-geneva-convention-to-protect-cyberspace.

139 "Microsoft dumps a 40-foot data center to the ocean floor off Scotland's coast", Digital Trends, 6 June 2018: https://www.digitaltrends.com/computing/microsoft-is-making-a-digital-atlantis-by-putting-data-centers-under-the-sea/.

140 "Demonstration of End-to-End Automation of DNA Data Storage". C. N. Takahashi, B. H. Nguyen, K. Strauss, L. Ceze; *Scientific Reports*; 2019, *9*, 4998. .DOI: 10.1038/s41598-019-41228-8.

141 "Explainer: What is a quantum computer?". *MIT Technology Review*, 29 January 2019: https://www.technologyreview.com/s/612844/what-is-quantum-computing/.

142 "Top 8 open source AI technologies in machine learning" M. J. Garbade; opensource.com; 2018: https://opensource.com/article/18/5/top-8-open-source-ai-technologies-machine-learning.

for example, or the call from some technology companies on regulating the use of facial recognition software).

(c) Developers of AI are reaching out to broader communities for guidance on how to use AI and to gain insight into how to best address security issues in the cyberworld, including through discussions on ethical issues.

Subitem 13(b): Digitalisation in the chemical industry

13.6 Dr Carsten Hoff (guest speaker, BASF) briefed the SAB on digitisation in the process industry,[143] which is benefiting from leveraging the value of data and new technologies. Digitialisation is increasing efficiency across value chains, enabling research and development, streamlining production processes and logistics (automated systems, predictive maintenance, and augmented reality tools for instant access to information are enablers in this context).[144] For training and archiving, every physical chemical production facility could have a digital twin that can be inspected using virtual reality.

13.7 Across supply chains, digital transformation provides visibility and transparency on a global scale, enabling shipment tracking (with the ability to interact with suppliers and transport providers) and via internet-of-things (IoT) devices monitoring the environment of the goods (for example, devices that record and transmit temperature, pressure, and mechanical stress measurements in real time). The increasing accessibility of data across all aspects of a company further enables interdisciplinary research, development, and innovation. An example was provided of modelling with AI for enzyme discovery.

13.8 Digital transformation is also viewed as a means to accelerate growth through allowing the potential for new and disruptive business models. For example, direct interaction with end-user customers through digital interfaces, for example, customer designed formulations, and laboratory guides for the use of chemical products.[145] Customer interaction provides an important aspect of the adoption of digital tools: digital transformation does not leave people out—it can actually create new opportunities.

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

(a) Digital transformation provides opportunities to improve chemical safety and security. In digital tools used in production lines, access to process and occupational safety information as well as safety alarms can be enabled.

---

143 (a) "Industry 4.0 and the chemicals industry". Deliotte Insights: https://www2.deloitte.com/insights/us/en/focus/industry-4-0/chemicals-industry-value-chain.html. (b) "Chemistry 4.0 – sustainable and digital", BASF, 18 January 2018: https://www.basf.com/global/en/who-we-are/sustainability/whats-new/sustainability-news/2018/chemistry-sustainable-and-digital.html.

144 Digitalisation at BASF: https://www.basf.com/global/en/who-we-are/digitalization.html.

145 For example, https://www.lab-assistant.basf.com/#/.

(b) Blockchains are frequently discussed when describing digital transformation; however, a very limited number of cases of usage have been demonstrated. Many companies are still exploring the use of distributed ledger approaches.

(c) Digitalisation activities influence a variety of functions across a chemical company. This also requires that all digitalised workflows be compliant with the relevant regulations and policies (for example, the requirement under the Convention).

(d) Digitalisation in industry has created some regulatory challenges as well. It is possible (and often useful) to create a digital twin (a digital picture) of a chemical production plant. This allows engineering partners, who may be in the territories of different States Parties, to transfer the plant's RI-Flowcharts into intelligent software systems. Providing these technical data to the engineering partners may be subject to authority permits if data of plants producing substances falling under the Convention are considered. License requirements for the export of substances falling under the Convention are valid for the substances itself, but also for export of knowledge, which takes place when the technical data for the plant is provided to engineering partners. Education and training on this trade control topic is key to avoid infringing upon the respective laws, and to support the challenging goal of such a digitalisation project.

Subitem 13(c): From EDNA to EDIS, the new electronic declarations platform

13.10 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 more efficiently comply with their obligations under the Convention. He discussed the tools available to the OPCW for enterprise content management, electronic declarations,[146] the secure exchange of information (SIX),[147] and data analytics. Each year, the OPCW receives 147 declarations and more than 16,000 forms. Ensuring the completeness, accuracy, and timeliness of declarations requires electronic tools.

13.11 The existing Electronic Declarations Tool for National Authorities (EDNA)[148] is a repository of facilities, chemicals, and historic declarations that automates and aggregates national data. It features automatic generation of declaration forms, an integrated OPCW Handbook on Chemicals,[149] warnings for data inconsistencies and incompleteness, analytical reports for validating the content of declarations, checks and validation of non-EDNA electronic declarations; and is available in all six OPCW official languages. There is a need to continue to bring forward improvements in

---

146 "Note by the Technical Secretariat: Electronic Submissions of Annual Declarations on Past Activities as at 31 May 2019" (S/1788/2010, dated 20 July 2019): www.opcw.org/sites/default/files/documents/2019/06/s-1766-2019%28e%29.pdf.

147 "Note by the Technical Secretariat: Update on the Secure Information Exchange System" (S/1662/2018, dated 21 August 2018): www.opcw.org/sites/default/files/documents/2018/08/s-1662-2018%28e%29.pdf.

148 Electronic Declarations Tool for National Authorities (EDNA): www.opcw.org/resources/declarations/electronic-declarations-tool-national-authorities-edna.

features and efficiency, and in this regard a new Electronic Declaration Information System (EDIS) will replace EDNA.

13.12 EDIS is a distributed system that is scalable to add new processes and business requirements. It features automated declaration package encryption, multi-user and multirole with granular role-based user access, a built-in repository of facilities, chemicals, and historic declarations, warnings for data inconsistencies and incompleteness, and inclusion of missing Article VI declaration forms and nil declarations.

13.13 In the subsequent discussion, the SAB expressed support for the continued development, improvement, and adoption of electronic tools for declarations. The benefits to completeness, accuracy, and timeliness of declarations are in the spirit of many recommendations from the SAB's 2015 report of the TWG on Verification.[53]

14. AGENDA ITEM FOURTEEN – The OPCW Laboratory

Subitem 14(a): Updates from the OPCW Laboratory

14.1 Dr Marc-Michael Blum (Head OPCW Laboratory) provided updates on the work of the OPCW Lab. He noted the accreditation of OPCW Laboratory to the updated ISO 17025 standard, briefed the SAB on a new laboratory information management system (LIMS), and discussed issues related to the validation of new equipment, noting that a number of older models of standardised and approved equipment have been discontinued by manufacturers. Dr Blum also provided updates on completed and upcoming environmental and biomedical proficiency tests,[150,151] biotoxin exercises, [152] OCAD updates,[153] and some research into biomarkers of toxic industrial chemicals.

---

150 (a) "Note by the Director-General: Evaluation of the Results of the Forty-Fifth Official OPCW Proficiency Test" (S/1778/2019, dated 25 July 2019): www.opcw.org/sites/default/files/documents/2019/07/s-1778-2019%28e%29.pdf, (b) "Note by the Director-General: Evaluation of the Results of the Forty-fourth Official OPCW Proficiency Test" (S/1739/2019, dated 27 March 2019): www.opcw.org/sites/default/files/documents/2019/03/s-1739-2019%28e%29.pdf, (c) "Note by the Director-General: Evaluation of the Results of the Fourth Official OPCW Biomedical Proficiency Test" (S/1776/2019, dated 24 July 2019): www.opcw.org/sites/default/files/documents/2019/07/s-1776-2019%28e%29.pdf, and (d) "Note by the Director-General: Evaluation of the Results of the Third Official OPCW Biomedical Proficiency Test" (S/1660/2018, dated 16 August 2018): www.opcw.org/sites/default/files/documents/2018/08/s-1660-2018%28e%29.pdf.

151 "Note by the Technical Secretariat: Call for Nominations for the Forty-sixth Official OPCW Proficiency Test" (S/1777/2019, dated 25 July 2019): www.opcw.org/sites/default/files/documents/2019/07/s-1777-2019%28e%29.pdf.

152 "Note by the Technical Secretariat: Call for Nominations for the Fourth Exercise on the Analysis of Biotoxins" (S/1780/2019, dated 28 July 2019): www.opcw.org/sites/default/files/documents/2019/07/s-1780-2019%28e%29.pdf.

153 (a) "Decision: Lists of Newly Validated Data on Scheduled Chemicals for Inclusion in the OPCW Central Analytical Database" (EC-91/DEC.2, dated 11 July 2019): www.opcw.org/sites/default/files/documents/2019/07/ec91dec02%28e%29.pdf, (b) "Note by the Director-General: Lists of Newly Validated Data on Scheduled Chemicals for Approval by the Executive Council for Inclusion in the OPCW Central Analytical Database" (EC-91/DG.5, dated 22 May 2019): www.opcw.org/sites/default/files/documents/2019/05/ec91dg05%28e%29.pdf, (c) "Decision: Lists of

14.2 Dr Blum also discussed the inclusion of optional samples requiring trace analysis in recent proficiency testing and the lessons learned. He noted that while there is interest in other new types of exercises, such as chemical forensics, resource constraints limit the number of exercises that can be run in addition to regularly scheduled proficiency testing. One new project that has been initiated (in cooperation with the designated laboratories) is the development of a high resolution orbitrap database, and data is being generated and compared across laboratories.

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

(a) Proficiency testing normally looks at samples in the parts-per-million (ppm) range, while analysis at lower levels continues to be a challenge.

(b) Among protein toxins, the biotoxin exercises have currently focused on ricin. If a laboratory can handle these analyses, it should also be capable of analysing other protein toxins.

(c) Toxin analysis exercises are being conducted by the OPCW and others.[154] Coordinating and sharing results will be important in identifying laboratories that can be called on by the OPCW if necessary.

Subitem 14(b): The OPCW ChemTech Centre

14.4 Ms Sakiko Hayakawa (Senior Planning officer) and Dr Marc-Michael Blum (Head, OPCW Laboratory) provided updated information on the project to upgrade the OPCW laboratory to a Centre for Chemistry and Technology (the ChemTech Centre).[155] Financing, project timelines, and the development of features and facility layouts were discussed. SAB members who had been involved in building laboratories were encouraged to share their experiences with the project team.

Newly Validated Data on Non-Scheduled Chemicals Relevant to the Chemical Weapons Convention for Inclusion in the OPCW Central Analytical Database" (EC-91/DEC.1, dated 11 July 2019): www.opcw.org/sites/default/files/documents/2019/07/ec91dec01%28e%29.pdf, (d) "Note by the Director-General: Lists of Newly Validated Data on Non-Scheduled Chemicals Relevant to the Chemical Weapons Convention for Approval by the Executive Council for Inclusion in the OPCW Central Analytical Database"(EC-91/DG.6, dated 22 May 2019): www.opcw.org/sites/default/files/documents/2019/05/ec91dg06%28e%29.pdf.

154 See for example: (a) European programme for the establishment of validated procedures for the detection and identification of biological toxins (EuroBioTox): https://eurobiotox.eu/, (b) Establishment of Quality Assurance for the Detection of Biological Toxins of Potential Bioterrorism Risk (EQuATox): http://www.equatox.org/.

155 "Note by the Technical Secretariat: Progress in the Project to Upgrade the OPCW Laboratory and Equipment Store to a Centre for Chemistry and Technology" (S/1769/2019, dated 9 July 2019): www.opcw.org/sites/default/files/documents/2019/07/s-1769-2019%28e%29.pdf.

15. AGENDA ITEM FIFTEEN – Future work of the Scientific Advisory Board

Subitem 15(a): The Director-General's response to the Scientific Advisory Board's recommendations to the Fourth Review Conference

15.1 Dr Forman reviewed the Director-General's response to the recommendations to the Fourth Review Conference.[156] He walked the SAB through the executive summary recommendations set out in RC-4/DG.1,[157] noting both the responses from the Director-General to specific recommendations and the views expressed in the Chairperson's informal report of the Fourth Review Conference.[44] The SAB's advice covered eight thematic areas: advice on advances in science and technology; advice on chemicals; advice on developments in chemical production and chemical discovery; advice on technologies for the delivery of toxic chemicals and drugs; advice on science and technology relevant to verification; advice on assistance and protection; advice on science and technology of relevance to chemical safety and security; and advice on scientific literacy and science advice.

Subitem 15(b): Scientific Advisory Board recommendations and the Verification Division

15.2 Dr Carolyn Browne (Director, Verification Division) provided the SAB with an overview of how recommendations from the SAB's report to the Fourth Review Conference that did not require action by the policy-making organs were being dealt with by the Verification Division.[158] In most cases, the recommendations were being acted on. In several cases, however, resource constraints have prevented the Secretariat from doing much. The Secretariat also did not support two recommendations.

15.3 Dr Browne indicated disappointment that the SAB recommendations for biomediated processes and concentrations of mixtures had not yet been adopted. She indicated the Verification Division would welcome input about the types of toxic chemicals that may pose new threats to the Convention. Additionally, Dr Browne emphasised her interest in continuing the frequent informal discussions between SAB members and staff members on verification-related issues and potential technical solutions.

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

(a) The SAB noted with appreciation the very detailed feedback on its past recommendations.

---

156 "Note by the Director-General: Response by the Director-General to the Report of the Scientific Advisory Board on Developments in Science and Technology for the Fourth Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention" (RC-4/DG.2, dated 1 June 2018): www.opcw.org/sites/default/files/documents/CSP/RC-4/en/rc4dg02_e_.pdf.

157 A quick reference guide to the executive summary of RC-4/DG.1 is available at: www.opcw.org/sites/default/files/documents/2018/10/SAB_RC4-Executive_Summary_Recommendations_-_web.pdf.

158 OPCW Verification Division: www.opcw.org/about-us/technical-secretariat/divisions/verification.

(b) The SAB appreciates the Secretariat's facilitation of informal dialogue on pertinent technical issues and possible technical approaches to address them. These discussions provide SAB members with greater insight into the needs and operating environment of the Secretariat. The SAB Secretary will continue to coordinate these interactions with those interested from the Secretariat.

(c) The Secretariat might consider creating a focal point for research and development efforts conducted within the OPCW.

(d) The possibility for States Parties to voluntarily share the results of research and development that can improve the capabilities of the Secretariat might be given consideration. As an example, the IAEA has accomplished this through a programme for technical support from Member States.[159]

Subitem 15(c): Scientific Advisory Board recommendations and the Inspectorate

15.5 Dr Evandro de Sousa Nogueira (Director of the Inspectorate) provided the SAB with an overview of the organisation of the OPCW Inspectorate and its operations.[160] He also discussed the recommendations from the SAB's report to the Fourth Review Conference that are being acted upon. Priority recommendations were identified from the SAB's advice on science and technology relevant to verification, advice on chemicals, and in keeping abreast of developments in science and technology. The Inspectorate serves as a point of coordination among the Verification Division, the International Cooperation and Assistance Division, and science and technology. Dr Nogueira indicated that engagement between the Inspectorate and the SAB aimed at sharing scientific knowledge was a priority.

Subitems 15(d): The Roadmap of work of the SAB, and 15(e): The Twenty-Ninth Session of the SAB

15.6 Recognising the magnitude of the undertaking of the scientific review,[161] the Board and Secretariat discussed the roadmap for the SAB and its Secretary to progress toward the Fifth Review Conference.

15.7 The SAB discussed its future work. The SAB is proposing to hold one session in 2020, and then meet for two sessions each year in 2021 and 2022. Additionally, the SAB will look to hold a series of international workshops in the period from 2020 to 2022. The SAB intends to hold its Twenty-Ninth Session in the first half of 2020, with the final date to be confirmed intersessionally. The schedule of meetings and workshops will be further developed at the 2020 session.

---

159 See for example Development and Implementation Support Programme for Nuclear Verification 2018 - 2019, IAEA Safeguards STR-386, 2018: https://www.iaea.org/sites/default/files/18/09/sg-str-386-development-support-programme.pdf.

160 OPCW Inspectorate: www.opcw.org/about-us/technical-secretariat/divisions/inspectorate.

161 After the Twenty-Seventh Session (and including the first meeting of the TWG on investigative science and technology), the review process that lead to the Report to the Fourth Review Conference consisted of 26 meetings and workshops that produced a total of 31 reports.

15.8 The SAB's report on developments in science and technology would be issued six to nine months prior to the Fifth Review Conference, so that:

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

(b) States Parties will be able to discuss science and technology developments in preparation for the review conference; and

(c) The Secretariat will be able to take science and technology advice into account when making substantive proposals to the Review Conference.

Subitem 15(f): Topics relevant to the report to the Fifth Review Conference.

15.9 The SAB members identified thematic topics to include when planning its science and technology review for the Fifth Review Conference. The areas reviewed in the report to the Fourth Review Conference serve as an overarching guide, with specific topics to be identified under each thematic heading. A list of relevant topics and information sources where information is currently available will be developed intersessionally. This list will serve as a basis to inform the SAB's programme of work.

16. AGENDA ITEM SIXTEEN – Developments in science and technology

16.1 Dr Forman discussed findings from the Secretariat's monitoring of trends and developments in scientific and patent literature. He provided perspectives on the trans-disciplinary nature of scientific development, and the need to look at capabilities rather than focus within familiar scientific disciplines.

16.2 Information technologies are recognised as amongst the most important in global research and development.[162] The impact of digital transformation is evident for the chemical sector, with AI tools for designing alternative chemical synthesis routes,[163] exploring "chemical space",[164] and enabling new approaches to automated and on-demand chemistry.[165] Industrially, large investments are being seen in the concept of a "Chemical Industry 4.0"[143] and mobile apps that provide instant access to chemistry information are being developed in academic settings.[166] Digitalisation has also

---

162 "Research & Development – 2019 Global R&D Funding Forecast", *R&D Magazine*,Winter 2019: https://learn.rdmag.com/20190115_gff_2019_rd_lp.

163 "Navigating around Patented Routes by Preserving Specific Motifs along Computer-Planned Retrosynthetic Pathways". K. Molga, P. Dittwald, B. A. Grzybowski; *Chem.*; 2019, *5(2)*, 460-473. DOI: 10.1016/j.chempr.2018.12.004.

164 "How to explore chemical space using algorithms and automation". P. S. Gromski, A. B. Henson, J. M. Granda, L. Cronin; *Nature Reviews Chemistry*, 2019, *3*, 119–128. DOI: 10.1038/s41570-018-0066-y.

165 (a) "Organic synthesis in a modular robotic system driven by a chemical programming language". S. Steiner1,J. Wolf. S. Glatzel, A. Andreou. J. M. Granda, G. Keenan, T. Hinkley, G. Aragon-Camarasa, P. J. Kitson, D. Angelone, L. Cronin; *Science*; 2019, *363(6423)*, eaav2211. DOI: 10.1126/science.aav2211. (b) "Digitization of multistep organic synthesis in reactionware for on-demand pharmaceuticals". P. J. Kitson, G. Marie, J.-P. Francoia, S. S. Zalesskiy, R. C. Sigerson, J. S. Mathieson, L. Cronin; *Science*; 2018, *359(6373)*, 314-319. DOI: 10.1126/science.aao3466.

166 "The 'OK, Molly'Chemistry". Yi Lu; *Acc. Chem. Res.*; 2017, *50(3)*, 647-651. DOI: 10.1021/acs.accounts.7b00009.

enabled the concept of "cloud laboratories", where experiments can be run by automated systems under the control of researchers at remote locations, and such systems have been set up as contract research services.[167]

16.3 Other developments highlighted by Dr Forman included enzymes capable of: assembling carbon-carbon bonds;[168] microorganisms engineered to produce plant-based drugs (e.g. opioids and cannabinoids[169]); metal-organic frameworks specifically designed to catalyse the degradation of chemical warfare agents;[170] a new method to determine molecular structures for small molecules from powdered solid samples;[171] 3D protein structures identified in living cells;[172] methods used to determine active ricin and ricin exposure in blood samples;[173] analysis of nerve agent exposure from dried blood spots;[174] the use of genetically modified plants to detect chemicals;[175] and wearable technology for possible pre-symptomatic detection of exposure.[176] New clinical and toxicological data sets[177] and new papers on toxidrome recognition of exposure to chemical agents[178] have also become available, and

---

167 "Companies in the cloud: Digitizing lab operations". M. May; Science; 2017: https://www.sciencemag.org/features/2017/02/companies-cloud-digitizing-lab-operations.

168 "Enzymatic assembly of carbon–carbon bonds via iron-catalysed sp3 C–H functionalization" R. K. Zhang, K. Chen, X. Huang, L. Wohlschlager, H. Renata, F. H. Arnold; *Nature*, 2018, *565*, 67–72. DOI: 10.1038/s41586-018-0808-5.

169 (a) "Discovery of new poppy enzyme might help improve yeast-based opiate synthesis". C. H. Arnaud; Chem. Eng. News.; 2018, 96(23): https://cen.acs.org/biological-chemistry/synthetic-biology/Discovery-new-poppy-enzyme-might/96/i23, and (b) "Complete biosynthesis of cannabinoids and their unnatural analogues in yeast". X. Luo, M. A. Reiter, L. d'Espaux, J Wong, C. M. Denby, A. Lechner, Yunfeng Zhang, Adrian T. Grzybowski, Simon Harth, Weiyin Lin, Hyunsu Lee, Changhua Yu, J. Shin, K. Deng, V. T. Benites, G. Wang, E. E. K. Baidoo, Y. Chen, I. Dev, C. J. Petzold, J. D. Keasling; *Nature*, 2019, *567*, 123–126. DOI: 10.1038/s41586-019-0978-9.

170 (a) "Computational evaluation of the chemical warfare agents capture performances of robust MOFs", C. V. Soaresa, A. A. Leitão, G. Maurin; *Microporous and Mesoporous Materials*, 2019, *280*, 97-104. DOI: 10.1016/j.micromeso.2019.01.046 (b) "Metal-organic frameworks: a breath of fresh air for gas masks". Monash University, 2018: https://phys.org/news/2018-06-metal-organic-frameworks-fresh-air-gas.html.

171 "Small Molecule Structures: A New World", D. Lowe, *Science*, 18 October, 2018: https://blogs.sciencemag.org/pipeline/archives/2018/10/18/small-molecule-structures-a-new-world.

172 "High-resolution protein 3D structure determination in living eukaryotic cells". T. TanakaT. Ikeya, H. Kamoshida, Y. Suemoto , M. Mishima, M. Shirakawa, P. Güntert, Y. Ito; Angew. Chem.; 2019, 58(22), 7284-7288, DOI: 10.1002/anie.201900840.

173 "Identifying exposures to ribosome-inactivating proteins in blood samples: amplification of ricin-induced ribosomal damage products enables sensitive detection of active toxin and circulating depurinated 28S rRNA". R. Falach, O. Israeli, Y. Gal, A. Sapoznikov, O. Shifman, S. Ehrlich, M. Aftalion, A. Beth-Din, T. Sabo, C. Kronman; *Forensic Toxicol.*; 2018 *36*, 375-. DOI: 10.1007/s11419-018-0414-0.

174 "Investigation of dried blood sampling with liquid chromatography tandem mass spectrometry to confirm human exposure to nerve agents". R. L. Shaner, R. M. Coleman N. Schulze, K. Platanitis, A. A.Brown, C. Seymour, P. Kaplan, J. Perez, E. I. Hamelin, R. C. Johnson; *Analytica Chimica Acta,*; 2018, *1033*, 100-107. DOI: 10.1016/j.aca.2018.06.049.

175 "Houseplants as home health monitors". C. N. Stewart, Jr, R. K. Abudayyeh,, S. G. Stewart; *Science*, 2018, *361(6399)*, 229-230. DOI: 10.1126/science.aau2560.

176 "Military applications of soldier physiological monitoring". K. E. Friedl; *J. Sci. Med. in Sport*; 2018, *21(11)*, 1147-1153. DOI: 10.1016/j.jsams.2018.06.004.

177 "Sarin: Potential Long-term Neurological Effects", Nationla Toxicology Program, United States Department of Health and Human Services, 2019: https://ntp.niehs.nih.gov/pubhealth/hat/noms/sarin/index.html .

178 "Toxidrome Recognition in Chemical-Weapons Attacks". G. R. Ciottone; *N. Engl. J Med,*; 2018; 378:1611-1620. DOI: 10.1056/NEJMra1705224.

research continues finding ways to improve medial countermeasures against chemical agents.[179]

16.4 In closing, Dr Forman reminded the SAB of its advice on taking practical views on new scientific developments,[180] highlighting reproducibility issues across scientific publications,[181] and a need to be cautious about "hype" related to new science and technology, regardless of whether it is beneficial or poses challenges to the implementation of the Convention.

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

(a) Capabilities for the recognition of unusual changes and symptoms that can reveal the signatures of toxic chemical presence, use, exposure, production, or dispersal are of considerable interest. Many technologies and data collection opportunities exist from monitoring environmental signatures (plants, insects, and gas sensing are pertinent examples), and can also be used for biological risk surveillance.[182] Such existing technologies may be worth exploring in order to determine their ability to catch signatures of toxic chemicals. The benefit may be that rather than try to develop unique new tools, existing tools may already be capable of providing useful information if appropriate data analysis tools (and data sets) are available.

(b) Further to recognising the signatures of toxic chemical exposure, the subjects of epidemiology, organ-on-chip technologies,[183] and the applications of sensor fusion were discussed as useful topics for consideration in the scientific review process. Sensor fusion was noted as a relevant topic for a SAB workshop and future SAB session briefings.

(c) The prevalence of scientific publications and access to information continues to raise questions and debate on how much information should actually be shared. Open-access science has many benefits for promoting and sharing scientific knowledge, as well as encouraging international scientific collaboration,[184] but the risk of available information being misused is an open question. Raising awareness among scientists on ethical issues and boosting visibility of the norms of the Convention and the security benefits it brings was encouraged as a means to discuss and address such issues.

---

179 Current approaches to enhancing oxime reactivator delivery into the brain". T. Kobrlova, J. Korabecny, O. Soukup; *Toxicology*, 2019, *423*, 75-83. DOI: 10.1016/j.tox.2019.05.006.

180 See paragraph 22 of RC-4/DG.1.

181 *Reproducibility and Replicability in Science*; National Academies of Sciences, Engineering, and Medicine, Washington, DC: The National Academies Press, 2019. DOI: 10.17226/25303.

182 "Technologies to address global catastrophic biological risks". C. Watson, T. K. Sell, M. Watson, C. Rivers, C. Hurtado, M. P. Shearer, A. Geleta, T. Inglesby; Hogns Hopkins Center for Health Security, 2018: http://www.centerforhealthsecurity.org/our-work/pubs_archive/pubs-pdfs/2018/180919-gcbr-tech-report.pdf.

183 "Advances in organ-on-a-chip engineering". B. Zhang, A. Korolj, B. F. L. Lai, M. Radisic; Nature Rev. Mat., 2018, *3*, 257–278. DOI: 10.1038/s41578-018-0034-7.

184 *Open Science by Design: Realizing a Vision for 21st Century Research*, National Academies of Sciences, Engineering, and Medicine, Washington, DC: The National Academies Press, 2018. DOI: 10.17226/25116.

(d) This overview of scientific and technological developments has been provided to the SAB each year since 2014; it has been well received and is considered to be highly informative.

17. AGENDA ITEM SEVENTEEN – Drafting of the report of the Twenty-Eighth Session of the Scientific Advisory Board

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

18. AGENDA ITEM EIGHTEEN – Any other business

Subitem 18(a): Departing SAB members

18.1 The SAB Chairperson bade farewell to the members of the SAB who are leaving the Board this year: Dr Pål Aas of Norway (in absentia), Dr Veronica Borrett of Australia, Dr Evandro de Sousa Nogueira[185] of Brazil and Dr Syed K. Raza of India. He thanked all of them for their commitment to the norms of the Convention, their distinguished service, and their substantive contributions to the SAB and the scientific review process for the Fourth Review Conference.

18.2 The Board bade farewell to Mr Cheng Tang, the 2019 Chairperson, who will also end his term of office at the end of the year. Mr Tang served on the TWG on verification, and as Vice-Chairperson from 2015-2018 he helped guide and facilitate the scientific review process that provided recommendations to the Fourth Review Conference. Mr Tang has also been a significant contributor to the productive engagement with States Parties that was enjoyed by the Board.

18.3 A moment of silence was observed for SAB member Mr Valentin Rubaylo of the Russian Federation, who recently passed away. Mr Rubaylo joined the SAB in 2014, served on the TWG on verification and made significant contributions to the scientific review process that formulated advice to the Fourth Review Conference. He had also served as member of the Secretariat as one of the first Chemical Demilitarisation Officers at the time of the entry-into-force of the Convention. Mr Rubaylo, a colleague, a friend, and a scientist, will be dearly missed.

Subitem 18(b): Briefing to States Parties

18.4 In the margins of the SAB's Twenty-Eighth Session, the SAB Chairperson and Vice-Chairperson briefed States Parties on 14 June 2018,[186] presenting an overview of the activities of the SAB to representatives of Afghanistan, Argentina, Australia,

---

185 Dr Nogueira resigned from the SAB in March 2019 before assuming his current post as Director of the OPCW Inspectorate.

186 Slides from the Chairperson's briefing are available at: www.opcw.org/sites/default/files/documents/2019/06/20190614%20SAB%20Briefing%20to%20States%20Parties.pdf.

Austria, Bangladesh, Brazil, Bulgaria, Canada, Chile, China, Cuba, Finland, France, Germany, Guatemala, Hungary, India, Indonesia, the Islamic Republic of Iran, Mexico, Morocco, the Netherlands, Norway, Pakistan, Poland, Qatar, the Republic of Korea, the Russian Federation, Slovenia, Switzerland, Venezuela, Ukraine, the United Kingdom of Great Britain and Northern Ireland, and the United States of America.

Subitem 18(c): Election of the Chairperson and Vice-Chairperson

18.5 In a closed session, the members of the Board elected Dr Christophe Curty as Chairperson and Dr Zrinka Kovarik as Vice-Chairperson for 2020.

Subitem 18(d): Acknowledgements

18.6 The SAB expresses its appreciation to the Director-General and the Deputy Director-General, as well as Dr Marc-Michael Blum, Mr Szymon Bochenski, Dr Carolyn Browne, Ms Francesca Capano, Dr Henrik Carlsson, Professor Robert P. Chilcott, Mr Larry Denyer, Ms Doris Eerhart, Dr Zaven Hakopov, Dr Eric Tan Lee Han, Ms Sakiko Hayakawa, Ms Barbara Hedler, Mr Alejandro Hernandez, Dr Michael Hoefer, Dr Carsten Hoff, Dr Shahriar Khateri, Dr Mei Lei, Dr Evandoro de Sousa Nogueira, Mr Santiago Oñate, Ms Irene O'Sullivan, Professor Bartłomiej Pączek, Mr Markus Siegert, Mr Sebastian Simonsen, Mr Maciej Surowiec and Mr Guy Valente for informative presentations and discussions during the Board's Twenty-Eighth Session. The SAB acknowledges Mr Lucas Benderitter, Mr Peter Brud, Ms Nadezda Malyutina, Ms Marlene Payva, Ms Giovanna Pontes, and Ms Ayah Wafi of the OPCW Office of Strategy and Policy for their support of, and contributions to, the Twenty-Eighth Session, its preparations, and this report. The SAB is grateful for the voluntary contributions that support its work received from Australia and Saudi Arabia, as well the European Union for its April 2019 Council decision, which provides funding for TWGs.

19. AGENDA ITEM NINETEEN – Adoption of report

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

20. AGENDA ITEM TWENTY – Closure of the session

The Chairperson closed the session at 16:34 on 14 June 2018.

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

Annex

LIST OF PARTICIPANTS IN THE TWENTY-EIGHTH SESSION OF THE SCIENTIFIC ADVISORY BOARD[187]

	Participant	Institution
1.	Professor Isel Pascual Alonso	University of Havana, Cuba
2.	Dr Khaldoun Bachari	Algerian Public Scientific and Technical Research Centre in the Physico-Chemical-CRAPC, Algiers, Algeria
3.	Dr Renate Becker-Arnold	BASF, Ludwigshafen, Germany
4.	Dr Veronica Borrett[188]	La Trobe University, Bundoora, Australia
5.	Ms Hoe-Chee Chua	DSO National Laboratories, Singapore
6.	Dr Christophe Curty[189]	Spiez Laboratory, Spiez, Switzerland
7.	Professor Vladimir Dimitrov	Institute of Organic Chemistry at the Centre of Phytochemistry, Bulgarian Academy of Sciences, Sofia, Bulgaria
8.	Professor Mostafa Ghanei, MD	Baqiyatallah University of Medical Sciences, Islamic Republic of Iran
9.	Mr Wilford Z. Jwalshik	Institute of Chartered Chemists of Nigeria
10.	Dr Zrinka Kovarik[190]	Institute for Medical Research and Occupational Health, Zagreb, Croatia
11.	Dr Andrea Leisewitz	Pontificia Universidad Católica de Chile
12.	Dr Robert Mikulak	U.S. Department of State, Washington, DC, the United States of America
13.	Dr Daan Noort	TNO, Rijswijk, the Netherlands
14.	Professor Ponnadurai Ramasami	University of Mauritius
15.	Mr Günter Povoden	EU CBRN Centres of Excellence Initiative, Ministry of Defence, Austria
16.	Dr Syed K. Raza	Chairperson Accreditation Committee, National Accreditation Board for Testing and Calibration Laboratories (NABL), India
17.	Professor Syeda Sultana Razia	Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh
18.	Professor Ahmed E. M. Saeed	Sudan University of Science and Technology, Khartoum, Sudan
19.	Mr Cheng Tang[191]	Office for the Disposal of Japanese Abandoned Chemical Weapons, Ministry of National Defence, Beijing, China
20.	Ms Farhat Waqar	Pakistan Atomic Energy Commission, Islamabad, Pakistan

[187] Dr Pål Aas, Dr Maciej Sliwakowski and Dr Yaseo Seto were unable to attend the Twenty-Eighth Session of the SAB.

[188] Chairperson of the temporary working group on investigative science and technology

[189] 2019 Vice-Chairperson of the SAB and 2020 Chairperson Elect of the SAB

[190] 2020 Vice-Chairperson Elect of the SAB

[191] Chairperson of the SAB

	Participant	Institution
21.	Professor and Dr Bartłomiej Pączek (guest speaker)	Captain, Polish Naval Academy, Gdynia, Poland
22.	Dr Henrik Carlsson (guest speaker)	Uppsala University, Sweden
23.	Professor Robert P. Chilcott (guest speaker)	University of Hertfordshire, United Kingdom of Great Britain and Northern Ireland
24.	Ms Doris Eerhart (guest)	Netherlands Forensic Institute
25.	Dr Eric Tan Lee Han (guest speaker)	DSO National Laboratories, Singapore
26.	Dr Carsten Hoff (guest speaker)	BASF, Ludwigshafen, Germany
27.	Dr Mei Lei (guest speaker)	Chinese Academy of Sciences, Beijing, China
28.	Ms Irene O'Sullivan (guest)	Netherlands Forensic Institute
29.	Mr Markus Siegert (guest speaker)	Bundeswehr Institute of Pharmacology and Toxicology, Munich, and Humboldt-Universität zu Berlin, Germany
30.	Mr Maciej Surowiec (guest speaker)	Microsoft, Inc., Brussels, Belgium
31.	Dr Jonathan Forman (Secretary to the Scientific Advisory Board)	Organisation for the Prohibition of Chemical Weapons, The Hague, the Netherlands

- - - o - - -