OPCW

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Twenty-Fourth Session
25 – 28 October 2016

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REPORT OF THE SCIENTIFIC ADVISORY BOARD AT ITS TWENTY-FOURTH SESSION 25 – 28 OCTOBER 2016

1. AGENDA ITEM ONE – Opening of the session

1.1 The Scientific Advisory Board (SAB) met for its Twenty-Fourth Session from 25 to 28 October 2016 at the OPCW Headquarters in The Hague, the Netherlands. The Session was chaired by Dr Christopher Timperley, with Mr Cheng Tang as Vice-Chairperson.

Executive summary

1.2 Pursuant to the deliberations of the SAB at its Twenty-Fourth Session, the following recommendations are presented to the Director-General in this report (see paragraphs 8.12 – 8.17 for further details).

(a) Given the information that chemical forensic and other modern investigative techniques can bring to investigations, it would be valuable to continue gathering information and understanding capabilities within this field. In this regard, the establishment of a temporary working group (TWG) should be considered. Participants could include forensic and other investigative experts and former OPCW inspectors, to explore how to develop forensic and other modern investigative methods and capabilities for verification under the Chemical Weapons Convention (hereinafter "the Convention").

(b) The Technical Secretariat (hereinafter "the Secretariat") should establish a system for the management of data, including compilation, curation, and analytics, obtained during contingency operations. This would enhance the investigative capacity of the Secretariat.

(c) Collection and curation of samples, analytical information, and annotation that may not be immediately actionable, are advisable. A searchable collection of physical objects and information is valuable for retrospective review. For example, existing compiled data on abandoned chemical weapons (ACWs) and impurity profiles for known synthetic routes to nerve and vesicant agents could serve as a resource for those working in the field of chemical weapons-related investigations.

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(d) Methods for the sampling and analysis of environmental and biomedical materials to determine exposure to chlorine and toxic industrial chemicals of relevance to the Convention should be investigated and/or developed.

(e) Recommended operating procedures for the Secretariat for sampling, handling, storage, and disposal of biomedical samples relevant to the Convention should be developed in collaboration with laboratories with biomedical sample expertise.

2. AGENDA ITEM TWO – Adoption of the agenda

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

1. Opening of the session
2. Adoption of the agenda
3. *Tour de table* to introduce Scientific Advisory Board members
4. Establishment of a drafting committee
5. Welcome address by the Deputy Director-General
6. Overview of developments at the OPCW since the last session of the Scientific Advisory Board
   - (a) General updates
   - (b) Status of the Scientific Advisory Board's recommendations
   - (c) Activities of the Technical Secretariat on "production by synthesis"
   - (d) Advisory Board on Education and Outreach
7. Developments in science and technology
   - (a) Spiez CONVERGENCE
   - (b) Phylopeptidomics
   - (c) Computational chemistry as a tool to study chemical warfare agents
   - (d) Industrial chemistry
8. Scientific and technological elements of verification technologies, emerging technologies, and new equipment
   - (a) Use of open source data for BTWC[1] compliance monitoring
   - (b) OPCW contingency operations

[1] BTWC = Biological and Toxin Weapons Convention.

(c) Science and technology capacity in the OPCW Inspectorate

(d) OPCW Rapid Response and Assistance Mission

(e) Unscheduled chemicals in the OPCW Central Analytical Database

(f) Report of the workshop on chemical forensics

9. Legacy chemical weapons

(a) Article IV and Verification Annex (Part IV (B)): old and abandoned chemical weapons

(b) Science and technology involved in the identification and destruction of abandoned chemical weapons

(c) Monitoring of Baltic Sea sediments and mussels for sea-dumped chemical warfare agents using GC-MS/MS[2] and LC-MS/MS[3] – results and challenges

10. Medical countermeasures and response to chemical agents

(a) Report of the workshop on the mechanism of action of chemical warfare agents

(b) Late effects of exposure to sulfur mustard

11. Science advice mechanisms

(a) Strengthening science advice for the BTWC

(b) United Nations Scientific Advisory Board

(c) International Criminal Court Scientific Advisory Board

12. Future work of the Scientific Advisory Board

(a) Discussion with Director-General

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

(c) Twenty-Fifth and Twenty-Sixth Sessions of the Scientific Advisory Board

(d) 2017 Scientific Advisory Board workshops

(e) Preparation of the Scientific Advisory Board's recommendations to the Fourth Review Conference[4]

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2 GC-MS/MS = gas chromatography-tandem mass spectrometry.

3 LC-MS/MS = liquid chromatography-tandem mass spectrometry.

13. Any other business

14. Adoption of the report

15. Closure of the session

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

A *tour de table* was undertaken to introduce the SAB members. 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 draft report of its Twenty-Fourth Session.

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

5.1 The Deputy Director-General of the OPCW welcomed the SAB members to the Twenty-Fourth Session of the Board, thanking the Chairperson, Vice-Chairperson, and the members of the board for their engagement with States Parties;[5] for exploring new and strengthening existing partnerships with other science-based organisations (especially the CTBTO,[6] BWC-ISU,[7] and IUPAC[8]) and scientific advisory boards; for the notable workshops and reports that have come out of the intersessional period; and for their efforts in communication and publications that raise awareness of the Convention and its objectives.[9]

5.2 Stressing that the use of toxic chemicals as weapons by anyone under any circumstances is reprehensible and completely contrary to the legal norms established by the international community, the Deputy Director-General spoke of recent reports and allegations of the use of chemical weapons, and the ongoing work of the OPCW Fact-Finding Mission in Syria. He emphasised that these reports and allegations are a matter of serious concern across the international community. These developments underscore the growing importance of the work of the SAB, and the tangible contributions it can make to the implementation of the Convention. Contributions that strengthen the scientific and technological capabilities of the OPCW and support the norms of the Convention could ultimately make the use of chemical weapons

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

5 The SAB Chairperson's briefing to States Parties at the Twenty-Third Session of the SAB is available online at: www.opcw.org/fileadmin/OPCW/SAB/en/21_April_SAB_Briefing_to_States_Parties-for_print.pdf. "Science for Diplomats" topics and presentations are available at: https://www.opcw.org/special-sections/science-technology/science-for-diplomats/

6 CTBTO = Comprehensive Nuclear Test Ban Treaty Organisation.

7 BWC-ISU = Biological Weapons Convention Implementation Support Unit.

8 IUPAC = International Union of Pure and Applied Chemistry.

9 For example, the 2016 Spring ConfChem: Science, Disarmament, and Diplomacy in Chemical Education: The Example of the Organisation for the Prohibition of Chemical Weapons, http://confchem.ccce.divched.org/2016SpringConfChem. Papers from this online conference will be published in a future edition of the peer-reviewed journal *Pure and Applied Chemistry*.

undesirable. Towards this end, advances in analytical capabilities enhance deterrence, and advances in medical countermeasures reduce the ability for these chemicals to cause harm. The Deputy Director-General further acknowledged recent statements from chemical societies, including the Seville Declaration of the European Association for Chemical and Molecular Sciences (EuCheMS)[10] and the IUPAC's endorsement of the Hague Ethical Guidelines,[11] as demonstrations of the strength of the norm against chemical weapons and the conviction of chemistry practitioners around the world to protect it.

5.3 Turning to the future of the OPCW and the shifting focus from destruction-related work to the complex task of preventing the re-emergence of chemical weapons, the Deputy Director-General encouraged the SAB to continue taking forward-looking and innovative stances and to think broadly when formulating advice and recommendations. In this regard, he advised the Board that engagement of the SAB with the recently initiated Open-Ended Working Group (OEWG) on the Future Priorities of the OPCW[12] will provide valuable opportunities to raise awareness of the technical and scientific dimensions underpinning the Convention, and to consider relevant SAB recommendations in the context of the OEWG's deliberations.

5.4 The Deputy-Director General concluded by thanking the SAB members who will be leaving the Board at the end of this year, commenting that the OPCW is fortunate in being able to draw on the expertise of this Board as we seek an enduring global commitment to the norms of the Convention.

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

Subitem 6(a): General updates

6.1 The Secretary to the SAB, Dr Jonathan Forman, reviewed developments at the OPCW since the SAB's Twenty-Third Session. He provided highlights from the Director-General's response to the SAB's most recent report (EC-82/DG.13, dated 7 June 2016),[13] presented general updates on the work of the OPCW, discussed SAB engagement with the OEWG on the Future Priorities of the OPCW, looked at potential for SAB involvement in forthcoming scientific conferences (including the CTBTO's 2017 Science and Technology Conference in June 2017; and the 17th Asian Chemical Congress[14] and 46th IUPAC World Chemistry Congress in July 2017[15]) and reviewed the ongoing work of the Board. The briefing included an overview of science and policy-maker engagement activities, with consideration given to making

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10 *The Seville Declaration on the Use of Chlorine in Warfare*, a statement endorsed by 36 chemical societies at the 6th European Association for Chemical and Molecular Sciences (EuCheMS) Chemistry Congress in Seville, Spain. More information is available at: http://www.euchems.eu/seville-declaration-use-chlorine-warfare/

11 For more information, see https://www.opcw.org/news/article/iupac-endorses-the-hague-ethical-guidelines/

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

13 Available at: www.opcw.org/fileadmin/OPCW/SAB/en/ec82dg13_e_.pdf

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

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

such engagement effective (using lessons learned from the OPCW SAB and the experiences of other science advice mechanisms). Planned activities for engaging policy-makers on the work of the SAB include the upcoming Eighteenth Annual Meeting of National Authorities in November 2016, and side-events at the BTWC's Eighth Review Conference[16] and the Twenty-First Session of the Conference of the States Parties to the Chemical Weapons Convention (hereinafter "the Conference")[17] in November and December 2016.

6.2 The SAB was pleased to see the Secretariat's work in reaching out and engaging with stakeholders. Notable in this regard were workshops organised by the OPCW's International Cooperation Branch for women in chemistry, and policy and diplomacy for scientists. Current and former SAB members participated in both of these events.

Subitem 6(b): Status of the Scientific Advisory Board's recommendations

6.3 Dr Stéphanie Daré-Doyen (from the Secretariat) updated the SAB on the status of the recommendations of the TWG on verification.[18] Her overview of the actions taken so far for the implementation of the 18 recommendations highlighted those recommendations discussed to date with States Parties during technical workshops or Industry Cluster consultations, in accordance with the Director-General's action plan (EC-80/DG.7, dated 28 August 2015).[19] She noted other recommendations that had been directly addressed by the Secretariat. Overall, significant progress had been achieved for 15 of the 18 recommendations.

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

(a) The SAB expressed its appreciation for the considerable efforts of the Secretariat to raise the visibility of the work of the TWG on verification and to engage States Parties on SAB recommendations. This has been a strength of the science advice mechanism of the OPCW.

(b) The SAB reiterated the importance of the evaluation of biosensors and tools for toxin analysis which, if suitable for OPCW requirements, could be adopted in due course as equipment used by the OPCW. Relevant examples of such tools currently in use were discussed in the Paris workshop (see subitem 10(a) of this report).

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16 For more information see: http://www.unog.ch/80256EE600585943/(httpPages)/57A6E253EDFB1111C1257F39003CA243?OpenDocument

17 For more information see: https://csp21.opcw.org/

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

19 The Impact of Developments in Science and Technology in the Context of the Chemical Weapons Convention (EC-80/DG.7, dated 28 August 2015). Available at: www.opcw.org/fileadmin/OPCW/SAB/en/ec80dg07_e_.pdf

Subitem 6(c): Activities of the Technical Secretariat on "production by synthesis"

6.5 Ms Barbara Hedler (from the Secretariat's Industry Verification Branch) provided updates on activities within the Secretariat related to the recommendations of the TWGs on convergence of chemistry and biology[20] and verification on the meaning of "production by synthesis", relevant to Article VI of the Convention. Two technical meetings were held in 2016 with experts from States Parties and the International Council of Chemical Associations (ICCA) to discuss recommendations 18[21] and 19[22] of the TWG on convergence, and recommendations 8[23] and 9[24] of the TWG on verification.

6.6 Ms Hedler noted that the different views among States Parties lead to many variations in implementation of the other chemical production facility (OCPF) verification regime. Further discussion is necessary to agree on a common understanding of OCPF verification regime obligations if there are to be consistent practices across the States Parties. In relation to the recommendation on "production by synthesis", a survey is being conducted across States Parties' chemical industries to provide additional data on the number and relevance of sites producing discrete organic chemicals (DOCs) via biochemical and biomediated processes (and to understand what the industries consider to be a "biomediated process"). In summary, more information and careful consideration are needed before any decision regarding these issues can be proposed to the policy-making organs. The survey results are expected to be available in mid-2017.

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

(a) The engineering processes and equipment in facilities that employ biotechnology for chemical production should not only be assessed for

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20 Convergence of Chemistry and Biology, Report of the Scientific Advisory Board's Temporary Working Group (SAB/REP/1/14, dated 27 June 2014). Available at www.opcw.org/fileadmin/OPCW/SAB/en/TWG_Scientific_Advsiory_Group_Final_Report.pdf

21 Recommendation 18 (TWG on convergence): "Taking into consideration the convergence of chemistry and biology as it relates to the synthesis of chemicals, the TWG was of the view that any process designed for the formation of a chemical substance should be covered by the term 'produced by synthesis'".

22 Recommendation 19 (TWG on convergence): "The TS should review the technical feasibility of converting a bio-based chemical processing facility to produce chemicals of concern to the CWC".

23 Recommendation 8 (TWG on verification): "The list of declarable OCPFs submitted by States Parties should include all facilities which fall under the definition/requirement of paragraph 1 of Part IX of the Verification Annex, regardless of the purity level of a DOC or DOC mixtures produced".

24 Recommendation 9 (TWG on verification): "Not all facilities that fall under Part IX of the Verification Annex should be considered of the same relevance to the object and purpose of the Convention. The TWG recommends a practical approach for enhancing the utilisation of verification resources for OCPF declaration and on-site inspection processes: (a) the OPCW policy-making organs should exempt certain OCPFs from declaration requirements; (b) the Secretariat should reassess which product group codes are highly relevant to the Convention. Facilities declared with these product group codes should be subject to a higher probability to be selected for inspection; and (c) for facilities in product group codes that are considered less relevant, the Secretariat should identify appropriate mechanisms to augment the declared information with validated and credible sources to allow for an assessment regarding the need for on-site inspection".

application to scheduled chemicals, but also for the overall capability to produce toxic substances.

(b) The SAB reiterated recommendation 10 of the report of the TWG on verification ("[t]he verification thresholds for OCPFs producing highly relevant chemicals, and the possibility of revision of the product group codes, should be addressed by the SAB as well as the industry cluster") in the context of impact of the meaning of "production by synthesis" on verification. This recommendation relates to risk to the Convention from facilities producing chemicals through biomediated processes.

(c) The different practices for declaration of biomediated processes reflect inconsistent definitions by States Parties of the terminology "biomediated". For example, some definitions would consider fermentation a biomediated process, but not fermentation using an enzyme catalyst, yet both are enzymatic processes. There are multi-step processes that combine fermentation with traditional chemical processes that produce products that are considered biomediated, and some States Parties include chemicals produced by natural sources under the category of biomediated production. In the view of the SAB, this latter definition serves to create further blurring of the issue; what defines natural, in a world where genetically-modified crops might be a source of raw materials, may not be clearly defined.

Subitem 6(d): Advisory Board on Education and Outreach

6.8 Dr Jean-Pascal Zanders (guest speaker, Chairperson of the OPCW Advisory Board on Education and Outreach (ABEO)) briefed the SAB on the activities of the ABEO.[25,26] The ABEO began functioning in 2016 and has held two meetings so far. The ABEO, which comprises 15 experts appointed by the Director-General following nomination by States Parties based on equitable geographic distribution, has also invited observers to its meetings, with the IUPAC having been designated a permanent observer. The ABEO advises the Director-General on matters relating to education, outreach, awareness-raising, and public diplomacy concerning the Convention and its implementation in relation to States Parties and key stakeholder communities. The topics considered by it may be raised by the Director-General. The ABEO can also consider specific issues within its mandate that it deems important.

6.9 After its second meeting, the ABEO has formulated recommendations on the organisation of the twentieth anniversary of the Convention, suggesting the holding of activities at the global, regional, and national levels, publicising the letters sent to the OPCW by national chemical societies and industry organisations that condemn the use of chlorine as a chemical weapon, youth outreach, civil society engagement, and a

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25 The ABEO was formed as an outcome of a recommendation from the SAB's TWG on education and outreach. The final report of the TWG: Education and Engagement: Promoting a Culture of Responsible Chemistry, Final Report of the Scientific Advisory Board's Temporary Working Group on Education and Outreach in Science and Technology Relevant to the Chemical Weapons Convention (SAB/REP/2/14, dated 25 November 2014) is available at: www.opcw.org/fileadmin/OPCW/SAB/en/Education_and_Engagement-v2.pdf

26 For additional information on the ABEO, including reports and related documents, see: https://www.opcw.org/about-opcw/subsidiary-bodies/advisory-board-on-education-and-outreach/

coherent public diplomacy strategy for the OPCW. It furthermore clarified the core concepts of "education", "outreach", and "public diplomacy" as distinct, but interrelated strategies. It also decided on the status and role of observers in the ABEO activities. Finally, the ABEO set out a work agenda for the intersessional period until the third meeting in the following areas: consideration of possible roles for National Authorities in education and outreach, the development of an overarching theme for education and outreach activities in different settings, the engagement of specific stakeholder communities, how to communicate about direct challenges to the Convention and the norm against chemical weapons, the engagement with other international organisations, longer-term strategies, youth outreach, and outreach at the regional, national, and local levels.

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

(a) The SAB expressed its appreciation to Dr Zanders for his presentation.

(b) There are several areas of common interest between the ABEO and the SAB, in particular the connections the SAB has made with other science advice mechanisms and the SAB's activities in science outreach.

(c) Working with National Authorities was discussed in the context of how to best raise awareness of chemical disarmament issues across States Parties and how to best engage the National Authorities themselves. Prioritisation of education relevant to the prevention of the re-emergence of chemical weapons varies across the States Parties, as does the mechanism through which each National Authority allows the Secretariat access to stakeholders within their State Party.

(d) The mandate of the ABEO includes developing educational materials. This may require additional funding sources; perhaps a trust fund similar to that of the SAB could be established.

7. AGENDA ITEM SEVEN – Developments in science and technology

Subitem 7(a): Spiez CONVERGENCE

7.1 Dr Christophe Curty briefed the Board on Spiez CONVERGENCE 2016, held from 6 to 8 September 2016 in Spiez, Switzerland.[27] His presentation began with an overview of the CONVERGENCE workshop series that Switzerland started in 2014 to discuss the convergence in chemistry and biology, and how advances in science and technology (S&T) may affect the Chemical and the Biological and Toxin Weapons Conventions. The workshop series is a Swiss contribution to an active and substantive S&T review process, the programme of which is the result of ongoing literature screening of developments in basic research, industry applications, and technical issues raised by the arms control community. The 2016 programme consisted of nine blocks, beginning with introductory lectures (Block 1) and concluding with a rapporteur session and policy discussion (Block 9). Blocks 2 to 8 included substantive technical presentations as follows:

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27 For more information see: http://www.labor-spiez.ch/en/die/sc/index.htm

(a) **Block 2** covered chemical synthesis, chemical modification, and large-molecule chemistry, and discussed developments in biomediated manufacturing of chemicals as technologies for converting biomass—sugars, starch, lignocelluloses—into chemical products, as well as the opposite approach synthesising complex molecules from small building blocks. A trend in the pharmaceutical industry is to move to biomediated processes to produce highly active pharmaceutical ingredients (HAPI). Such production plants are technologically highly complex and contain safety standards that are similar to those of high-safety biological facilities. In many aspects HAPI production plants resemble Schedule 1 facilities, but because of their production profile they remain under the Convention declaration threshold for DOC-producing facilities. A further approach for synthesising chemicals is engineering the genome with the aim of converting cells into virtual chemical factories. Recent advances in gene editing enable a shift from reading to writing and editing genomes, and reprogramming cells. The technology is costly and faces many challenges for industrial applications.

(b) **Block 3** covered additive manufacturing (3D printing), which has in recent years been presented as a development with potential security risks, and showed the apparent limitation of this technology. This process is an excellent tool for fast prototyping and producing repairs but is less suitable for large-scale industrial manufacturing of critical high performance pieces. Promising developments were discussed with regard to 3D printing using biological materials. The goal of reproducing biological function by "organ printing" remains a big challenge. 3D printing of biological materials is today a research tool utilised to model tissue functions.

(c) **Block 4** covered genome editing technologies that were included in a 2016 United States threat assessment[28] and therefore received much attention from an arms control perspective. Site-directed genome engineering aims at specific modifications of cellular properties—a further step in technological advancement after the lowering of costs in sequencing technology has led to large databases and a better understanding of biological systems. CRISPR[29] Cas9[30] permits the introduction of changes to DNA within cells and provides the ability to edit genetic code accurately and precisely. The technology is utilised for the development of a broad range of new bio-based products, including therapeutics, antimicrobials, animal health products, and genetically modified crops.

(d) **Block 5** was complementary to the genome editing discussions, focusing on advances in omics technologies and their utility for the study of biological systems at the molecular level.

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28 J. R. Clapper; Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community; Senate Armed Services Committee, 9 February 2016. Available at: https://www.dni.gov/files/documents/SASC_Unclassified_2016_ATA_SFR_FINAL.pdf

29 CRISPR = clustered regularly interspaced short palindromic repeats.

30 CAS9 = CRISPR associated protein 9.

(e) **Block 6** examined research into the memory and programming capability of biological systems to overcome shortcomings in existing technology. Due to the drop in the cost of DNA sequencing and DNA synthesis technology, the long-term storage of large amounts of data in DNA is technically possible today. This research is increasingly linked to synthetic biology and can be combined with gene editing tools such as CRISPR.

(f) **Block 7** covered "DNA origami", a technology currently at the stage of fundamental research with currently few recognised practical applications. DNA origami uses single-stranded DNA for building nanostructures that are used to modulate their mechanical stiffness. The goal of this research is to create molecular structures that interact in a type of "nanofactory" or to develop molecular robotics.

(g) **Block 8** turned to policy and ethical questions, where participants discussed whether or not convergence may result in questions around the scope of the Chemical and the Biological and Toxin Weapons Conventions in relation to new materials and processes, and their implementation. In terms of scope, assessing how developments fall under the general purpose criterion of the treaties requires a good understanding of the new technology and continuous review of potential future developments. The S&T developments display promising benefits for society, but their exploitation for harmful purposes by various actors in the context of their dual-use potential cannot be disregarded.

7.2 The report from Spiez CONVERGENCE 2016 is in preparation and will be presented to States Parties during side events at the forthcoming BTWC Eighth Review Conference, and the Twenty-First Session of Conference of the States Parties to the Convention on 30 November. The Third Spiez CONVERGENCE workshop is planned for early September 2018.

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

(a) The SAB thanked the government of Switzerland for organising and funding the CONVERGENCE series of workshops, which provide a mechanism for continuing review of the convergence of chemistry and the life sciences, following the completion of the terms of reference of the SAB's TWG on convergence in 2013. The Spiez CONVERGENCE 2014 and 2016 reports contain information that will be used to inform the SAB's S&T report to the Fourth Review Conference on the topic of convergence and its relevance to the Convention.

(b) Understanding the engineering/limitations of equipment and processes required for biomediated production of chemicals is valuable for OPCW inspectors.

(c) A useful topic to address under the convergence umbrella is the use of biology to protect against chemicals, for example, bioscavengers developed as medical countermeasures (a topic covered in the report of the Paris workshop of the SAB, described under subitem 10(a)).

(d) A question was asked on whether stagnation of chemical warfare agent development (e.g. the elimination of military programmes of States Parties to

the Convention and hence the absence of dedicated research programmes to produce new chemical warfare agents) is countered by advances brought forward from convergence of the sciences in defence against chemical agents (making the use of chemical warfare agents effective for those who are properly equipped to use them and protect themselves from exposure). Consideration of this question may influence the perception of the impact of convergence on chemical disarmament.

(e) Block 8 of the CONVERGENCE workshop included a discussion on whether nanotechnologies fall under either the Chemical or the Biological and Toxin Weapons Conventions. Examples at the workshop provided by legal scholars suggested they may not. The discussion at Spiez concluded that if nanotechnologies have an impact on life processes by chemical or biological means, they would be covered under the general purpose criteria of the Conventions.

Subitem 7(b): Phylopeptidomics

7.4 Dr Jean Armengaud (guest speaker, French Alternative Energies and Atomic Energy Commission (CEA)) briefed the SAB on high-throughput omics approaches, e.g. genomics-transcriptomics-proteomics, which can be usefully combined for defining biomarkers for diagnostic purposes. The field of proteogenomics[31] is aimed at integrating these large-scale data for improving genome annotation, and identifying specific molecular targets that could define a given biological phenomenon. In addition to better characterisation of biological systems, these approaches may be used for detecting and quantifying organisms without any *a priori* information.

7.5 Dr Armengaud described methodologies relevant for toxin and pathogen identification. These include methods such as whole-cell MALDI-TOF[32] and tandem MS. Whole-cell MALDI-TOF is an MS approach routinely applied in medical microbiology, which provides a global protein signature for any organism and enables identification of any pathogen. Tandem-MS is a more informative method that allows identification of several thousand peptide sequences. This information enables detection of pathogens with high precision and without any *a priori* information, even in the presence of complex matrices and in mixtures. This approach, derived from meta-proteomics, performs as well as meta-genomics, but faster. It can be applied to samples without the need for culture. Several examples illustrated the potential of this novel methodology for characterising unknown but harmful samples, uncultivatable micro-organisms, and complex microbiota. Because a one-hour MS measurement is sufficient to get an overview of the microbiota of rich samples, a wealth of new information can be made possible to benefit those working in the fields of chemical

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31 M. Locard-Paulet, O. Pible, A. Gonzalez de Peredo, B. Alpha-Bazin, C. Almunia, O. Burlet-Schiltz, J. Armengaud; Clinical implications of recent advances in proteogenomics; *Expert Review Of Proteomics*, 2016, *13(2)*, 185 – 199. DOI: 10.1586/14789450.2016.1132169.

32 MALDI-TOF = matrix assisted laser desorption ionisation-time of flight MS.

and biological disarmament[33] and defence, human health, and environmental monitoring.[34]

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

(a) The SAB expressed its appreciation to Dr Armengaud for his presentation. His work represents a pertinent example of the convergence of the sciences through the integration of advances in chemistry, biology, and informatics.

(b) The SAB engaged the speaker on whether or not omics approaches can be used for understanding changes in gene expression, the formation of adducts to proteins and/or DNA, and other biological changes induced through exposure to toxic chemicals. While such studies can be complicated, it was felt that advances in these fields and integration of data across the "omes" (e.g. genomes, transcriptomes, proteomes, metabolomes) show promise for a better understanding of toxicity mechanisms.

(c) Integrated approaches to the use of omics measurements and omics databases can be compromised by errors in the recorded data. A number of studies have shown that contaminated sequences are present in many genomic databases[35,36] and may need to be accounted for to ensure accuracy in results. Several approaches to ensuring quality and cleaning up contaminated sequence information were described. One approach is to use the matching of protein and gene sequences to recognise and annotate database information, in effect using the integration of complementary data streams to recognise and correct errors.

(d) The work described at CEA focused on broad screening and identification. However, antibody-based enrichment strategies can also be applied, giving these methods utility in targeted analysis.

(e) The omics approaches described lend themselves to the use of non-model organisms as "sentinel' species for ecotoxicology (for example *Gammarus fossarum*).[37] The use of such methods may require chemometric approaches looking at the interactions of a system of specific markers for exposure to a given toxic agent. In principle, alerts from sentinel species can also be detected by visual observation (as recently reported for chemical agents with *Blaptica*

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33 E. Duriez, J. Armengaud, F. Fenaille, E. Ezan; Mass spectrometry for the detection of bioterrorism agents: from environmental to clinical applications; *J Mass Spectrom*, 2016, *51*, 183-199. DOI: 10.1002/jms.3747

34 J. Armengaud, Next-generation proteomics faces new challenges in environmental biotechnology; *Curr Opin Biotechnol*; 2016, *38*, 174-182. DOI: 10.1016/j.copbio.2016.02.025.

35 O. Pible, E. M. Hartmann, G. Imbert, J. Armengaud; The Importance of Recognizing and Reporting Sequence Database Contamination for Proteomics; *EuPA Open Proteomics*, 2014, *3*, 246 -249. DOI: 10.1016/j.euprot.2014.04.001.

36 O. Pible, J. Armengaud; Improving the quality of genome, protein sequence, and taxonomy databases: a prerequisite for microbiome meta-omics 2.0; *Proteomics*, 2015, 15, 3418-3423. DOI: 10.1002/pmic.201500104.

37 P. Y. Kunz, C. Kienle, A. Gerhardt; Gammarus spp. in Aquatic Ecotoxicology and Water Quality Assessment: Toward Integrated Multilevel Tests; *Rev. Environ. Contam. Toxicol.;* 2010*, 205,* 1-76. DOI: 10.1007/978-1-4419-5623-1_1.

dubia),[38] with more conclusive biomarker analysis performed at the time of alert. A literature survey on the use of sentinel species may be informative for a better understanding of what is possible and of potential value for further research.

Subitem 7(c): Computational chemistry as a tool to study chemical warfare agents

7.7 Professor Ponnadurai Ramasami briefed the Board on the use of computational chemistry in the study of chemical warfare agents. Computational chemistry is a branch of chemistry that uses theoretical calculations to probe chemistry and interdisciplinary problems. An overview of the literature in which computational methods were used to study chemical weapons was given, followed by a description of a project currently being investigated, the "micro solvation of sulfur mustard". The study of micro solvation of substances in the gas phase can lead to information for better understanding chemical stability, solubility and interpretation of infrared and MS spectra. Experimental studies alone may not provide all the required parameters to understand fully the chemistry of chemical weapons, and thus computational chemistry is a useful supplementary tool.

7.8 In the subsequent discussion, the SAB noted that computational chemistry is a useful research tool across all fields of chemistry, including the development of medical countermeasures, action of decontaminants, design of catalysts, and chemical synthesis.

Subitem 7(d): Industrial chemistry

7.9 Dr Nicia Mourão reviewed the use of biomass in the production of biofuels and biobased industrial chemicals using case studies from Brazil. She spoke about a bioeconomy that relies on renewable resources to generate sustainable energy and manufacture industrial chemicals, and, at the same time, safeguards food security. She discussed how the development of new technologies based on renewable raw materials has the potential to bring about a dramatic change in global energy and chemical production, citing claims that this new sector can be a suitable alternative to existing chemical production practices to ensure the prospects of future generations. The presentation provided useful insights into the growth and development of biobased industries brought about through international partnerships.

7.10 Professor Ferruccio Trifirò briefed the SAB on efforts to find less toxic alternatives to the industrial use of hydrogen cyanide (HCN), phosgene, and chlorine: three toxic industrial chemicals that have served as chemical weapons. While there are known alternative chemistries to the use of HCN and phosgene, a suitable chemistry to replace chlorine use in industrial chemical production has not been found.

7.11 HCN was one of the first fumigants (as an insecticide and rodenticide) to be used extensively in modern times, with declining use in recent years. Industrially, production of adiponitrile (a monomer for nylon 6-6) and methacrylic acid (a

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38 F. Worek, T. Seeger, K. Neumaier, T. Wille, H. Thiermann; Blaptica Dubia as Sentinels for Exposure to Chemical Warfare Agents – a Pilot Study; *Toxicology Letters;* 2016*, 262,* 12-16. DOI: 10.1016/j.toxlet.2016.09.006.

monomer for polymethacrylate) accounts for 90% of HCN use. Professor Trifirò described alternative routes that do not involve HCN to produce these chemicals.

7.12 Phosgene is used mainly to produce toluene diisocyanate, methylene diphenyl diisocyanate, and polycarbonates. There are several well developed alternatives to the use of phosgene; however, they are currently not economically suitable to replace typical industrial use of phosgene.

7.13 Elemental chlorine is used in the manufacture of organic compounds (63% of industrial use), in the manufacture of inorganic chlorine compounds (18% of industrial use), and to produce bleaches and disinfection products (19% of industrial use). For the chemical products generated directly from chlorine, no suitable alternative chemistries have yet been developed.

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

(a) The SAB noted that green chemistry and biomass-based production methods are complementary to one another and provide potential pathways for reducing the use of toxic chemicals in industrial processes. The SAB is of the opinion that the Secretariat's continued monitoring of the "bioeconomy" is valuable for recognising and understanding technological changes in the chemical industry and viable technologies to reduce the use of more toxic chemicals.

(b) It was further noted that, despite low oil prices resulting in many biobased commodity chemicals being economically unfavourable, further diffusion of biotechnology into fine and speciality chemicals continues.

8. AGENDA ITEM EIGHT – Scientific and technological elements of verification technologies, emerging technologies, and new equipment

Subitem 8(a): Use of open source data for BTWC compliance monitoring

8.1 Dr Mirko Himmel (guest speaker, Research Group for Biological Arms Control) described research from his Hamburg University group on the use of open source data for compliance monitoring. The work focuses on the BTWC, which entered into force in 1975 and bans the development, production, and stockpiling of biological and toxin weapons. The BTWC is considered a successful disarmament treaty, because it provides for the full and complete disarmament of biological weapons. Article I of the BTWC prohibits any use of bacteriological or other microbial agents or toxins for hostile purposes, making the Convention clear and strong in its aims and scope. However, the BTWC lacks a verification mechanism, requiring that confidence building within the BTWC regime rely on surrogates based on voluntary instruments such as form-based annual declarations.

8.2 Dr Himmel pointed out that with the absence of a legally binding verification mechanism, increasing transparency regarding relevant Member States' activities requires alternative means. One solution is the development of a publicly applicable, non-biased method to collect and analyse BTWC-related open source information in a structured way. The aim would be to present a set of qualified questions about certain activities rather than definite conclusions. Currently, at the Research Group for Biological Arms Control at the University of Hamburg's Centre for Science and

Peace Research, an appropriate web-tool is in development for the use of open source data for compliance monitoring. Funding for this project is provided by the German Federal Foreign Office. While open source data monitoring by non-governmental actors cannot replace an official verification procedure, proponents of this approach are confident that enhanced (public) transparency is indispensable in biological disarmament and will contribute to confidence building among States Parties, ultimately strengthening the BTWC.

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

(a) The SAB expressed its appreciation to Dr Himmel for his presentation.

(b) As the project from Hamburg is designed to produce an online and publicly available tool, its ultimate utility would require "crowdsourcing" to provide all possible data streams (in principle ensuring accuracy and eliminating bias). To take further action on the basis of an indication, however, would need a suitable review mechanism.

(c) A useful platform would require appropriate informatics tools and means to filter and eliminate erroneous information from databases.

(d) Developing a publicly accessible online tool of this kind provides a way to gain experience in the use and analysis of open source datasets, and to suitably refine analysis methods through harnessing ideas and inputs from a potentially broad and diverse community of users.

(e) The application of the web-link being created by the Hamburg group for chemical monitoring was discussed. While the system is specifically designed to collect biologically relevant information, with relevant data streams and indicators identified, the system would in principle be adaptable for use with chemically relevant information.

Subitem 8(b): OPCW contingency operations

8.4 Mr Lennie Phillips (OPCW Inspectorate Division, Operations and Planning Branch) provided an overview of the contingency operations of the OPCW, describing the organisational structure and processes used in decision making to initiate a contingency operation, mission planning, and lines of communication. He followed this with a discussion on some of the available analytical equipment used in investigations and the opportunities and considerations for the adoption of new technologies. He noted that, although non-routine investigations have a certain degree of flexibility based on the purpose of the mission and new equipment can be quickly tested under field conditions, procurement and acceptance on the equipment list for routine operations are subject to more stringent and formal processes.

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

(a) The value of having access to portable devices (including biosensors and point of care diagnostic devices) that can quickly detect the presence of toxic chemicals and biological toxins was considered. It was noted that the unpredictability of field situations makes it difficult to anticipate what analytical

methods would be needed in any given situation. Additionally, purchasing devices in anticipation of specific investigation scenarios may provide inspectors with sets of equipment that never see use.

(b) The SAB noted that from the outside, much of the operational work of the OPCW appears to be "a closed box". Public engagement describing some of the mechanisms of decision making and modalities of contingency operations could be useful in helping the general public understand the complexities of multilateral diplomacy and the many dimensions that are considered as inputs in decisions. Such an endeavour would enhance OPCW public diplomacy.

Subitem 8(c): Science and technology capacity in the OPCW Inspectorate

8.6 Dr Gareth Williams (OPCW Inspectorate Division, Safety and Analytical Chemistry Cell) briefed the Board on the Inspectorate's S&T capacity. The Cell aims to be the focal point within the Inspectorate for scientific and technical capability. The Cell is responsible for ensuring that the Inspectorate has an operational chemistry capability to support routine inspections and other investigations relevant to the Convention. The Cell is made up of about 30 inspectors with experience in process chemistry, chemical engineering, clinical sciences, emergency response (paramedic), synthetic chemistry, and analytical chemistry. To support ongoing projects and short-term requirements, the Cell is divided into five teams: Safety, Medical, Research and Development, Specialist Training, and Engagement and Outreach. These teams are multi-divisional in composition, and draw upon expertise across the Secretariat (including beyond the Inspectorate).

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

(a) The Safety and Analytical Chemistry Cell is a new structure within the Secretariat that is developing activities and establishing its role in cooperation with other units. Given the S&T relevance of the Cell, the SAB looks forward to receiving future updates and identifying areas in which its advice may be of value to the cell.

(b) The Engagement and Outreach team is intended to engage with external parties for finding technological solutions to issues identified by the Inspectorate in its work. The function is to understand what scientific and technological capabilities already exist and could be easily adopted for a given purpose.

(c) Training materials for inspectors might usefully serve as educational materials for general education and outreach activities of the Secretariat. In this regard, Inspectorate staff involved in technology assessment and method development projects could usefully publish some of their work in the scientific literature to support education and outreach.

Subitem 8(d): Rapid Response and Assistance Mission

8.8 In a joint presentation, the Head of the OPCW's Assistance and Protection Branch, Mr Shawn DeCaluwe and the Head of the OPCW's Inspectorate Capacity-Building and Contingency-Planning Cell, Mr Mehran Rouzbahani briefed the SAB on the Rapid Response and Assistance Mission (RRAM). The RRAM is based on paragraphs

8 and 11 of Article X of the Convention and consists of a team of OPCW experts that is deployed at short notice to assist a State Party affected by an unexpected chemical incident or attack (including from the action of non-State actors).[39] Capabilities of the RRAM include providing advice or assistance on response procedures, preservation and collection of evidence, sampling and analysis, remediation, facilitation of supplementary assistance, and coordination with other responding organisations. In situations where it is unsuitable for the RRAM to deploy, or where it is unnecessary for OPCW staff to be on site, remote assistance and advice would also be available.

8.9 In the subsequent discussion, the difference between the RRAM and the established processes for Article X assistance and protection missions was discussed. Article X assistance and protection missions are developed for situations in which States Parties help other States Parties; the RRAM can be initiated at the request of a State Party or through a State Party accepting an offer of assistance from the Secretariat.[40]

Subitem 8(e): Unscheduled chemicals in the OPCW Central Analytical Database (OCAD)

8.10 Dr Hugh Gregg (Head of the OPCW Laboratory) presented a potential path forward that should enable the Council to approve the addition of data of non-scheduled chemicals relevant to the Convention in the OPCW Central Analytical Database (OCAD). Essentially, before the start of a sampling and analysis mission, the inspection team leader and a representative of the inspected State Party jointly determine the scope of the OCAD to be utilised for that specific mission. This scope, at a minimum, includes data for all scheduled chemicals, and their analytical derivatives, that are included in the OCAD; this is the same scope as is currently in use. Additional non-scheduled data may be added to the scope of the inspection; this non-scheduled data would help to minimise false positives and would enhance the analysis capability during investigations of alleged use.

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

(a) Eliminating false positives will not resolve the issue of detection of chemical reaction by-products that are included in the schedules of chemicals,[41] which if present would likely be detected.

(b) The SAB reiterated its previous advice on the OCAD:[42] "If a chemical is not included in the OCAD, an inspection team may fail to identify it during on-site

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39 Establishment of a Rapid Response Assistance Team (S/1381/2016, dated 10 May 2016). Available at: www.opcw.org/fileadmin/OPCW/S_series/2016/en/s-1381-2016_e_.pdf

40 Guidelines for States Parties Requesting a Rapid Response and Assistance Mission (S/1429/2016, dated 17 October 2016). Available at: www.opcw.org/fileadmin/OPCW/S_series/2016/en/s-1429-2016_e_.pdf

41 For those unfamiliar with this issue, the 17 March 2015 Science for Diplomats briefing covered the topic and is available at: www.opcw.org/fileadmin/OPCW/CSP/C-18/en/TIMPERLEY_Science_for_Diplomats.pdf

42 Report of the Scientific Advisory Board on Developments in Science and Technology for the Third Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention (RC-3/DG.1, dated 29 October 2012). Available at: www.opcw.org/fileadmin/OPCW/CSP/RC-3/en/rc3dg01_e_.pdf

sampling and analysis. This is important, not only for scheduled chemicals, but also for relevant non-scheduled chemicals—for example, a non-scheduled degradation product of a Schedule 1 chemical (as a possible indicator of production or use) or a non-scheduled toxic chemical, such as a riot control agent that has been used for activities prohibited by the Convention." In this regard, the SAB noted that the proposal described by Dr Gregg would strengthen the OCAD while alleviating concerns from States Parties regarding false positives resulting from an analysis.

(c) The SAB suggested that adding data for unscheduled chemicals to the OCAD is an issue that requires engagement with National Authorities so that they can understand more completely the technical basis of the proposed additions and also understand why such additions are of value. The Secretariat might consider using S&T breakout sessions at National Authorities Meetings, Science for Diplomats briefings, and/or Industry Cluster consultations as suitable venues for further engagement on this issue.

Subitem 8(f): Report of the workshop on chemical forensics

8.12 The first of the four workshops intended to inform the report to the Fourth Review Conference, covering "Chemical Forensics: Capabilities across the Field and the Potential Applications in Chemical Weapons Convention Implementation", was held from 20 to 22 June 2016 in Helsinki, Finland.[43] The workshop was organised by the SAB in cooperation with the Finnish Institute for the Verification of the Chemical Weapons Convention (VERIFIN) and funded through Project III (Science and Technology: Assessment of Developments in Science and Technology) of European Union Council decision 2015/259/CFSP, dated 17 February 2015.

8.13 Professor Paula Vanninen briefed the SAB on the workshop, presenting the key findings and executive summary of the workshop report (SAB-24/WP.1, dated 14 July 2016).[44] She explained that forensic science is defined as the study of traces (remnants of presence and/or activity).[45,46] These remnants serve as silent witnesses that need to be detected and understood to make reasonable inferences during investigations. Chemical forensics is a methodology used to obtain information from chemical remnants relevant to investigative questions. Just as fingerprints and DNA can provide unique signatures that can be used to identify individuals, chemical samples can provide distinctive signatures (for example through their impurities and/or isotopic ratios) that might reflect how and where they originated.[47] Combining chemical forensics information with other data sources could provide information that

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43 See OPCW news item: https://www.opcw.org/news/article/scientists-review-the-science-of-chemical-forensics-and-potential-applications-in-chemical-weapons-investigations/

44 Available at: www.opcw.org/fileadmin/OPCW/SAB/en/sab24wp01_e_.pdf

45 Forensic Science on Trial. Proceedings of the Plenary Presentations from the 20th ANZFSS International Symposium on the Forensic Sciences, Sydney 2010; *Australian Journal of Forensic Sciences*, 2011, *43 (2-3)*, 89-103. Available at: http://www.tandfonline.com/toc/tajf20/43/2-3

46 C. Roux, F. Crispino, O. Ribaux. From Forensics to Forensic Science; *Current Issues in Criminal Justice*, 2012, *24 (1)*, 7-24. Available at: http://www.austlii.edu.au/au/journals/CICrimJust/2012/16.pdf

47 B. Halford. Tracing A Threat; *Chemical and Engineering News*, 2012, *90 (6)*, 10-15. Available at: http://cen.acs.org/articles/90/i6/Tracing-Threat.html

can be used to ascertain the origins of a chemical agent or reconstruct the event in which it has been used.

8.14 The workshop reviewed current capabilities in chemical forensics and considered how these—and other forensic—methods might be applicable to investigations of incidents relevant to the Convention. Experts in chemical and forensic analysis from a broad range of fields were assembled to share experiences and discuss topics, including: investigations of the use of chemical weapons, evidence collection, forensic intelligence, chemical forensics in illegal drug analysis, biomedical sample analysis, and chemical analysis techniques used in other investigative and retrospective analytical applications.

8.15 The SAB endorsed the report and discussed the proposals from the executive summary (paragraph 1.5 of SAB-24/WP.1), which are as follows:

(a) "Given the information that chemical forensic techniques can bring to investigations, it would be valuable to continue gathering information and understanding capabilities within this field. In this regard, additional workshops or a TWG could be considered. Participants would include forensic experts, forensic practitioners and OPCW inspectors, to explore how to develop forensic methods and capabilities for Chemical Weapons Convention verification." *[subparagraph 1.5(a) of SAB-24/WP.1]*

(b) "Appropriate functions within the OPCW could benefit from cooperative working relationships with organisations and networks of experts relevant to forensics." *[subparagraph 1.5(b) of SAB-24/WP.1]*

(c) "Establishing a system for the management of data, including compilation, curation and analytics, is essential for use in a forensic capacity. In a chemical weapons investigation context, requirements (including those of associated infrastructure and support) would need to be defined." *[subparagraph 1.5(c) of SAB-24/WP.1,]*

(d) "Collection and curation of samples, analytical information and annotation that may not be immediately actionable is advisable. A searchable collection of physical objects and information is valuable for retrospective review. For example, existing compiled data on abandoned chemical weapons and impurity profiles for known synthetic routes to nerve and vesicant agents could serve as a resource to those working in the field of chemical weapons related investigations." *[subparagraph 1.5(d) of SAB-24/WP.1]*

(e) "Methods using impurity profiling and isotopic ratio distribution for purposes related to determining responsibility for use of chemical weapons, for abandoned chemical weapons, or for clandestine chemical weapons production are valuable to develop. The possible profiling of impurities not related to the product, such as solvents, trace metals and inorganic elements, should be considered." *[subparagraph 1.5(e) of SAB-24/WP.1]*

(f) "Recent developments in biomedical sampling methods for determining exposure to chlorine were discussed. Consideration should be given to development of biomedical methods for determining exposure to other toxic

industrial chemicals that might be used as chemical weapons. Development of Recommended Operating Procedures for the sampling of biomedical materials, and their handling and storage, is valuable in such investigations." *[subparagraph 1.5(f) of SAB-24/WP.1]*

(g) "Autonomous systems to support investigations of alleged use of chemical weapons could benefit investigators, in addition to their use for sampling and on-site analysis and in detection systems." *[subparagraph 1.5(g) of SAB-24/WP.1]*

(h) "Forensic training will continue to be valuable for enhancing forensic awareness and forensic investigation capabilities." *[subparagraph 1.5(h) of SAB-24/WP.1]*

(i) "Workshop participants recognised the value of broader engagement with experts from other disciplines using forensic approaches in which chemistry plays a key role. The Technical Secretariat would benefit from continuing to find such opportunities to share experiences with relevant communities of experts." *[subparagraph 1.5(i) of SAB-24/WP.1]*

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

(a) The SAB expressed its appreciation to the Board members and the invited speakers who participated in the Helsinki workshop, and to VERIFIN.

(b) The SAB reiterated the value of engaging broadly with forensic practitioners to develop recommendations directed at delivering scientific and technological solutions to support investigations that are relevant to the Convention. This would be most effectively accomplished through a TWG.

(c) Given the relevance of investigative methods and technologies to recent work of the Secretariat and to the overall objective of preventing the re-emergence of chemical weapons, the SAB is of the opinion that such a TWG would consider investigative methods that support field operations, including chemical forensics and sampling methodologies for Convention-relevant materials. This TWG could begin meeting in mid- or late 2017.

(d) The SAB also noted that the American Chemical Society Spring Meeting (April 2017) will include a series of symposia on chemical forensics and a workshop to establish an international network of scientists within the field. A number of the participants in the Helsinki workshop have received invitations to participate. In light of the recommendations for a TWG, experts from within this network could be called upon as necessary to share their experiences and insights.

8.17 The following proposals derived from the report of the Helsinki workshop, specifically proposals (a), (c), (d), and (f) in paragraph 8.15, are put forward as recommendations of the SAB at its Twenty-Fourth Session:

(a) Given the information that chemical forensic and other modern investigative techniques can bring to investigations, it would be valuable to continue

gathering information and understanding capabilities within this field. In this regard, establishment of a TWG should be considered. Participants could include forensic and other investigative experts and former OPCW inspectors, to explore how to develop forensic and other modern investigative methods and capabilities for verification under the Convention.

(b) The Secretariat should establish a system for the management of data, including compilation, curation, and analytics obtained during contingency operations. This would enhance the investigative capacity of the Secretariat.

(c) Collection and curation of samples, analytical information, and annotation that may not be immediately actionable are advisable. A searchable collection of physical objects and information is valuable for retrospective review. For example, existing compiled data on ACWs and impurity profiles for known synthetic routes to nerve and vesicant agents could serve as a resource to those working in the field of chemical weapons-related investigations.

(d) Methods for sampling and analysis of environmental and biomedical materials to determine exposure to chlorine and toxic industrial chemicals of relevance to the Convention should be investigated and/or developed. Subsequently, recommended operating procedures could be developed.

(e) Recommended operating procedures for the Secretariat for sampling, handling, storage, and disposal of biomedical samples relevant to the Convention should be developed in collaboration with laboratories with biomedical sample expertise.

9. AGENDA ITEM NINE – Legacy chemical weapons

Subitem 9(a): Article IV and Verification Annex (Part IV(B)): old and abandoned chemical weapons

9.1 Sven Devroe (OPCW Verification Division, Chemical Demilitarisation Branch) provided an overview of the Secretariat's ongoing work involving old chemical weapons (OCWs) and ACWs. Up to this year, 16 States Parties have declared a combined total of over 140,000 OCWs and declarations continue each year. OCWs and ACWs pose unique challenges as these items are generally recovered after decades of burial. Munitions are frequently damaged, leaking, fused, and armed, making identification difficult and hazardous. Non-destructive evaluation techniques are crucial in identification, and destruction methods must be able to handle any specific features of OCWs and ACWs. Several inspections are performed each year to verify new recoveries of weapons, monitor destruction, and verify destruction records against a site inventory. Technical knowledge on chemical munitions and their ageing processes is essential for these verification activities.

9.2 The SAB expressed its appreciation to Mr Devroe and the important work of the Chemical Demilitarisation Branch, noting the difficulties encountered in these projects.[48]

Subitem 9(b): Science and technology involved in the identification and destruction of abandoned chemical weapons

9.3 Mr Cheng Tang provided a presentation entitled "Identification of Abandoned Chemical Weapons". He reviewed the requirement of the Convention in respect of the regime of ACWs, noting that the Secretariat must retain the capability to "verify the origin of the abandoned chemical weapons and establish evidence concerning the abandonment and identity of the Abandoning State" (paragraph 11 of Part IV(B) of the Verification Annex). He provided a case study on the subject of the ACWs discovered in China. The presentation discussed how the origin of an Abandoning State can easily be established in most cases through physical observation and identification; however, in some cases, it can be difficult to establish immediate scientific evidence. Examples of the latter include ACWs found in non-original bulk agent containers or those chemical agents having undergone preliminary neutralisation. Using modern analytical techniques (in particular, using $^{13}C/^{12}C$ isotope ratios), it was possible to define the "fingerprint" of the chemical agents and to establish the identity of the Abandoning State.

9.4 Dr Koji Takeuchi provided a presentation focusing on technical aspects of OCW and ACW destruction. He described technical challenges and the technological solutions employed in the ACW removal and destruction projects in China and Japan.

9.5 In the subsequent discussion of the two presentations, the following points were raised:

(a) The SAB observed that China and Japan have demonstrated a successful model of how States Parties to the Convention can work together towards the goal of a world free of chemical weapons. The partnership shows how difficult technical problems can be addressed through scientific collaboration and strong government-industry relationships.

(b) Building databases of information specific to historical chemical weapons programmes is highly valuable for assisting the identification of OCWs and ACWs. Impurity profiles in sulfur mustard, for example, can be used to differentiate stockpiles from which a given munition may have originated.[49] Information collected from OCWs and ACWs has much value in chemical forensic applications.

(c) ACWs, and historical sites where chemical munitions have been burned in pits, have an environmental impact of which the effects have been reported in

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48 The April 2016 issue of the OPCW Science and Technology Monitor provides weblinks to a number of scientific publications concerning OCWs and ACWs. It can be accessed here: www.opcw.org/fileadmin/OPCW/Science_Technology/Monitor/OPCW_S_T_Monitor_3_2.pdf

49 S. Hanaoka, K. Nomura, T. Wada: Determination of Mustard and Lewisite Related Compounds in Abandoned Chemical Weapons (Yellow Shells) from Sources in China and Japan; *Journal of Chromatography A*, 2006, *1101 (1-2)*, 268-277.

the scientific literature.[50] Environmental remediation, including collection and removal of contaminated soil, is another important aspect of ACW projects.

Subitem 9(c): Monitoring of Baltic Sea sediments and mussels for sea-dumped chemical warfare agents using GC-MS/MS and LC-MS/MS – results and challenges

9.6 Professor Paula Vanninen briefed the SAB on the research on environmental and ecotoxicological effects of sea-dumped chemical munitions in the Baltic Sea, including the Bornholm area (40,000 tons) and Skagerrak (170,000 tons). Mapping, sampling, analysis, modelling, ecotoxicology, and tools for decision making have been and will be reported between 2006 and 2019 in the MERCW,[51] CHEMSEA,[52] MODUM,[53] and DAIMON[54] projects. In such multidisciplinary research projects, the role of VERIFIN has been, and is, to develop methods and analysis for sediment and water samples, and mussels and fish samples for chemical warfare agents or their degradation products, metabolites, and biomarkers.

9.7 So far, across these projects, 692 sediment samples have been analysed and 16 target chemicals identified. The DAIMON project has also identified new chemicals using LC-ESI/MS/HRMS (hybrid orbitrap instrument). Concentrations of arsenic containing chemicals in sediment samples from Bornholm Deep have been found to be as high as 40,000 µg/kg (40 ppm).

9.8 Soft tissue from *in-vivo* exposed mussels has also been studied. High concentrations of oxidised diphenylchloroarsine (DA) and adamsite (DM) were measured. The study of the metabolism of chemical warfare agents is essential, since there is no information as to which metabolites are formed in fish and mussels. This is challenging due to complex sample matrices and a need to synthesise reference chemicals (e.g. glutathione-, protein- or DNA-adducts). Further fish and mussel analysis will be conducted using *in-vitro*, *in-vivo* and *in-situ* experiments to get a better overview of the possible ecotoxicological effects of dumped chemical munitions. All data produced in previous projects, as well as in the DAIMON project, will be used for the evaluation of the risk posed by these munitions to the environment and humans, as well as for the evaluation of techniques to recover these munitions.

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50 H. Thouina, L. Le Forestier, P. Gautret, D. Hube, V. Laperche, S. Dupraz, F. Battaglia-Brune; Characterization and Mobility of Arsenic and Heavy Metals in Soils Polluted by the Destruction of Arsenic-Containing Shells from the Great War; *Science of The Total Environment*, 2016, *550*, 658 – 669.

51 MERCW = Modelling of Ecological Risks Related to Sea-Dumped Chemical Weapons. More information is available at: http://cg.cs.uni-bonn.de/en/projects/mercw/

52 CHEMSEA Findings: Results from the CHEMSEA Project – Chemical Munitions Search and Assessment; CHEMSEA Project, 2014. Available at: http://www.iopan.gda.pl/MODUM/ http://www.chemsea.eu/admin/uploaded/CHEMSEA%20Findings.pdf

53 MODUM: Towards the Monitoring of Dumped Munitions Threat.

54 DAIMON = Decision Aid for Marine Munitions. More information is available at: http://www.syke.fi/en-US/Research__Development/Research_and_development_projects/Projects/Decision_Aid_for_Marine_Munitions__DAIMON/Decision_Aid_for_Marine_Munitions__DAIMO(38493)

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

(a) HELCOM[55] (Baltic Marine Environment Protection Commission – Helsinki Commission) has recommended not recovering the Baltic Sea munitions, given the hazards and risks of greater dispersion of hazardous materials. There are, however, concerns related to munitions picked up by fishing boats and engineering projects[56] that might disturb current dump sites. Objective studies are of critical importance on this issue.

(b) The study of the Baltic Sea munitions has revealed new information regarding the environmental fate of chemical agents, including identifying bacteria that are capable of metabolising degradation products of sulfur mustard.[57]

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

Subitem 10(a): Report of the workshop on the mechanism of action of chemical warfare agents

10.1 The second of the four workshops intended to inform the report to the Fourth Review Conference, on "Chemical Warfare Agents: Toxicity, Emergency Response and Medical Countermeasures", was held on 26 and 27 September 2016 in Paris, France.[58] The workshop was organised by the SAB in cooperation with Secrétariat Général de la Défense et de la Sécurité Nationale (SGDSN). Funding for this workshop was provided in part through Project III (Science and Technology: Assessment of Developments in Science and Technology) of European Union Council Decision 2015/259/CFSP, dated 17 February 2015, and in part by the SGDSN.

10.2 Dr Zrinka Kovarik briefed the SAB on the workshop, presenting the key findings and the executive summary of the workshop report (SAB-24/WP.2, dated 14 October 2016).[59] The workshop emphasised that effective emergency response and medical treatment form a frontline defence against the use of chemical agents. The more effective the ability to respond and counter the effects of chemical agents, the less effective are chemical weapons. Staying abreast of developments related to the toxicology of chemical warfare agents, clinical detection of exposure and medical response (both short- and long-term) is of vital importance. In this regard, understanding the molecular biological mechanisms and the chemistry[60] through which chemical agents exert their toxic effects is critical for the development of more effective medical countermeasures and treatments for survivors of exposure.

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55 For more information on HELCOM see: http://www.helcom.fi/

56 A. Benn, P. P. Weaver, D. S. M. Billet, S. van den Hove, A. P. Murdock, G. B. Doneghan, T. Le Bas; Human Activities on the Deep Seafloor in the North East Atlantic: an Assessment of Spatial Extent; *PLoS ONE*, 2010, *5(9)*, e12730. DOI: 10.1371/journal.pone.0012730.

57 N. Medvedeva, Y. Polyak, H. Kankaanpää, T. Zaytseva; Microbial responses to mustard gas dumped in the Baltic Sea; *Marine Environmental Research*, 2009, *68 (2)*, 71-81.

58 See OPCW news item: https://www.opcw.org/news/article/scientific-advisory-board-reviews-the-science-of-medical-response-to-toxic-chemical-exposure/

59 Available at: www.opcw.org/fileadmin/OPCW/SAB/en/sab-24-wp02_e_.pdf

60 D. Ajami, J. Rebek, Jr.; Chemical Approaches for Detection and Destruction of Nerve Agents; *Org. Biomol. Chem.*, 2013, *11*, 3936-3942.

10.3 The workshop brought together experts from relevant scientific fields and stakeholders in chemical security to discuss and review current knowledge and practices in toxicology and emergency response to chemical warfare agent exposure. This workshop complements earlier SAB reports reviewing currently available medical countermeasures and treatments for chemical warfare agent exposure,[61,62] as well as the OPCW's guide for first responders to a chemical weapons attack.[63]

10.4 The SAB endorsed the report and discussed the proposals from the executive summary (SAB-24/WP.2, paragraph 1.5), which are as follows:

(a) "There has never been a greater need to find fast and efficient means to diagnose and treat people who have been exposed to toxic chemicals. Research into more effective methods continues and many gaps still exist. Developments across the fields should be regularly monitored and efforts made to bring experts working in both civilian and governmental organisations together to share best practices." *[subparagraph 1.5(a) of SAB-24/WP.2]*

(b) "New approaches to address old and continuing problems must also be considered. For example, sulfur mustard was first used as a weapon of war almost 100 years ago, yet to this day the precise mechanism by which it produces blisters is not understood. Only when it is, will it be possible to rationally design drugs that could be used to reduce or prevent blistering." *[subparagraph 1.5(b) of SAB-24/WP.2]*

(c) "Treatment of exposure to toxic chemicals requires medical countermeasures and decontamination procedures (for victims of exposure, infrastructure and the environment). Appropriate consideration must be given to both aspects when evaluating procedures for response to chemical incidents." *[subparagraph 1.5(c) of SAB-24/WP.2]*

(d) "Much literature and information exists on how to respond to chemical incidents. There is little standardisation internationally (even to the point that some responders are not allowed to deploy countermeasures that are stockpiled for use in emergencies by others). The procedures are in many cases specifically tailored to certain groups (e.g. military, emergency responder, etc.) and for a general civilian population may not represent best practices. A compilation of information categorised by who it is meant to apply to might be considered as a reference collection." *[subparagraph 1.5(d) of SAB-24/WP.2]*

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61 Response to the Director-General's Request to the Scientific Advisory Board to Provide Further Advice on Assistance and Protection (SAB-21/WP.7, dated 29 April 2014). Available at: www.opcw.org/fileadmin/OPCW/SAB/en/sab-21-wp07_e_.pdf

62 Response to the Director-General's Request to the Scientific Advisory Board to Provide Further Advice on Assistance and Protection (SAB-22/WP.2/Rev.1, dated 10 June 2015). Available at: www.opcw.org/fileadmin/OPCW/SAB/en/sab-22-wp02_e_.pdf.

63 *Practical Guide for Medical Management of Chemical Warfare Casualties* (OPCW, 2016). Available at: www.opcw.org/fileadmin/OPCW/ICA/APB/Practical_Guide_for_Medical_Management_of_Chemical_Warfare_Casualties_-_web.pdf

(e) "The collation and consolidation of information that can aid responders to incidents involving chemical and/or biological agents could be valuable to ensure access to pertinent information. The Technical Secretariat in collaboration with the SAB may wish to consider updating and reissuing relevant technical documents (toxin fact sheets, for example)." *[subparagraph 1.5(e) of SAB-24/WP.2]*

(f) "On-site and point-of-care detection methods to identify exposure and trigger responses to chemical agent exposure represent a first line of defence. Given the time-critical nature of treatment, a thorough review and evaluation of existing tools would be valuable for verification and investigative purposes." *[subparagraph 1.5(f) of SAB-24/WP.2]* In discussing this recommendation of the workshop, the SAB wished to clarify its meaning. As on-site and point of care systems become capable of detecting signals of toxic materials in real time, they can also be used to time stamp and collect information. Of relevance to verification, is the real time detection and alert to inspectors, who may use the signals to initiate an appropriate response to exposure. Of relevance to investigations, the data collected can be helpful in reconstructing past events.

(g) "Biosensors are valuable tools for point-of-care detection of chemicals. There may be opportunities to make better use of plant biomarkers for measuring and detecting (possibly in real time) toxic chemical exposure. A literature review and/or proof-of-concept research project (funded through international cooperation and/or other suitable funding opportunities) might be considered." *[subparagraph 1.5(g) of SAB-24/WP.2]*

(h) "There are many overlapping methods and technical dimensions in response to chemical agents and biological toxins, another example of the convergence of chemistry and biology. Efforts should be made to build networks that bridge communities of medical and emergency responders to share best practices and experience. These networks could be used to help maintain strong links between the SAB and the BTWC community." *[subparagraph 1.5(h) of SAB-24/WP.2]*

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

(a) The SAB expressed its appreciation to the Board members and the invited speakers who participated in the Paris workshop, and to the SGDSN.

(b) In regard to proposal (h) in the previous paragraph, the workshop report will be shared with States Parties to the BTWC during a side event on the subject of the OPCW SAB at the BTWC Eighth Review Conference in November 2016.

(c) July 2017 will be the centenary of the first use of sulfur mustard; it may be an opportunity to liaise with the ABEO to discuss the technical dimensions and history of the development and dual-use of mustard agents. This may further lend itself to thematic topics for the twentieth anniversary events of the OPCW.

Subitem 10(b): Late effects of exposure to sulfur mustard

10.6 Professor Mohammad Abdollahi described the potential delayed toxic effects that can manifest after exposure to sulfur mustard.[64,65] Sulfur mustard is cytotoxic in nature, targeting a variety of tissues, and can induce long-term complications in the body. Long-term genotoxic effects depend on the extent of exposure and it is possible to induce some reproductive complications in the next generation. The key mechanism of action of sulfur mustard is DNA alkylation along with production of reactive oxygen species (ROS) and nicotinamide adenine dinucleotide (NAD) depletion. In general, DNA damage, cell death, and defects in the cell membrane are frequently observed in sulfur mustard-exposed individuals. Although there is not enough data available to understand the molecular biological basis of the mechanism of action, there are case studies supporting the correlation between physical anomalies in children whose fathers are exposed to sulfur mustard. Regarding the epigenetic effects of sulfur mustard, drugs with potential to counteract delayed genotoxic effects are being developed; these include DNA methyltransferase (DNMT) inhibitors and biologically active peptides.

11. AGENDA ITEM ELEVEN – Science advice mechanisms

Subitem 11(a): Strengthening science advice for the BTWTC

11.1 Dr Robert Mikulak briefed the SAB on the ongoing discussions concerning science advice mechanisms for the BTWC. Although the review of the BTWC takes into account any relevant scientific and technological developments, no procedure for doing so is specified. Initially, a few Member States provided their own analyses. Later, such analyses were supplemented by summaries prepared by the treaty Secretariat and groups of science academies and by discussions on agreed topics during annual one-week "meetings of experts". However, the lack of dedicated time and adequate expertise, as well as the lack of a means to sum up and assess the issues discussed, has led to a renewed effort to develop a better approach for adoption at the Eighth Review Conference in November 2016.

11.2 Dr Mikulak noted that two approaches were under discussion: an advisory group with limited membership allocated among regional groups or, alternatively, participation by all interested experts. He stressed the need to provide adequate staff and financial resources to enable the advice mechanism to work effectively.

11.3 As at 28 October 2016, the following States Parties had submitted papers to the Eighth Review Conference regarding science advice and/or the review of scientific developments: Finland, Norway, and Sweden (joint paper);[66] the Islamic Republic of

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64 M. Balali-Mood, M. Hefazi; Comparison of Early and Late Toxic Effects of Sulfur Mustard in Iranian Veterans; *Basic & Clinical Pharmacology & Toxicology*; 2006, *99 (4)*, 273-282. DOI: 10.1111/j.1742-7843.2006.pto_429.x.

65 A. Ghorani-Azam, M. Balali-Mood; Clinical Pharmacology and Toxicology of Mustard Compounds, in: *Basic and Clinical Toxicology of Mustard Compounds*, M. Balali-Mood, M. Abdollahi (Eds.); Springer International Publishing, Switzerland, 2015, 63-100. ISBN: 978-3-319-23873-9.

66 Elements on Science and Technology for the 2016 Review Conference – the Importance of an Active Review Process (BWC/CONF.VIII/PC/WP.7, dated 25 April 2016); submitted by Finland, Norway, and Sweden. Available at:

Iran;[67] the Russian Federation;[68] Spain;[69] Switzerland;[70,71] the United Kingdom of Great Britain and Northern Ireland;[72,73] and the United States of America.[74] The InterAcademy Partnership has also produced a report with proposals.[75]

11.4 In the subsequent discussion, the SAB noted the many areas of common interest and expressed the desire to work closely with a new BTWC science advice mechanism.

Subitem 11(b): United Nations Scientific Advisory Board

11.5 Dr Hayat Sindi (guest speaker, United Nations Scientific Advisory Board) spoke to the SAB about motivating scientists to align science with the needs of people and policy makers (including work related to the United Nations Sustainable Development

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http://www.unog.ch/80256EDD006B8954/(httpAssets)/2F9E5E5B65480FF9C1257FA3004C1C43/$file/BWC_CONF.VIII_PC_WP.7.pdf

67 The BTWC Review Process of Science and Technology (BWC/CONF.VIII/WP.12, dated 21 October 2016); Submitted by the Islamic Republic of Iran. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/EEABB1903E791177C1258057004E8573/$file/BWCCONF.VIIIWP.12.pdf

68 Strengthening the Biological Weapons Convention Proposal for the Establishment of a Scientific Advisory Committee (BWC/CONF.VIII/PC/WP.2/Rev.2, dated 4 July 2016); submitted by the Russian Federation. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/49B8741C96902E9CC1257FF000359BBB/$file/BWCCONF.VIIIPC2.Wp2.Rev.2.pdf

69 Reviewing Science and Technology within the BWC: Elements for a Politically Independent Process (BWC/CONF.VIII/PC/WP.27, dated 10 August 2016); submitted by Spain. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/298425B0439119DAC125800D002D896E/$file/BWCCONF.VIIIPCWP.27.pdf

70 Strengthening the BWC Science and Technology Review Process (BWC/CONF.VIII/PC/WP.8, dated 25 April 2016); submitted by Switzerland. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/63DA30B5C7B281E8C1257FA3004C2BAD/$file/BWC_CONF.VIII_PC_WP.8.pdf

71 Strengthening the BWC Science and Technology Review Process: Considerations regarding the Composition of an S&T Review Body (BWC/CONF.VIII/PC/WP.16, dated 19 July 2016); submitted by Switzerland. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/4B2C4755FFD094DDC1257FFB0035F806/$file/BWCCONF.VIIIPCWP.16.pdf

72 A Future Science and Technology Review Process (BWC/CONF.VIII/PC/WP.4, dated 11 April 2016); submitted by The United Kingdom of Great Britain and Northern Ireland. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/CC2D1DD486F0ED28C1257FA3004BDDC3/$file/BWC_CONF.VIII_PC_WP.4.pdf

73 Review of Developments in Science and Technology: Key Points from the 2012-2015 BTWC Intersessional Programme (advance version). Submitted by the United Kingdom of Great Britain and Northern Ireland. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/5B18B27F802C7B06C125805A0056DBC8/$file/20160930-UKWP_8RC_ST_Final3.pdf

74 Science and Technology Review for the BWC: Features of an Effective Process (BWC/CONF.VIII/PC/WP.3, dated 11 April 2016); submitted by the United States of America. Available at: http://www.unog.ch/80256EDD006B8954/(httpAssets)/A012B78B0DCDDBFCC1257FA3004BCF73/$file/BWC_CONF.VIII_PC_WP.3.pdf

75 The Biological and Toxin Weapons Convention Considerations for a Science Advisory Mechanism, The InterAcademy Partnership (IAP), April 2016. Available at: http://www.iapbwg.pan.pl/images/files/reports/2016/IAP_BWC_Science_Advisory_Process_roundtable_report.pdf

Goals), her work in promoting women in science, and her involvement in the United Nations Secretary-General's SAB (UN SAB). The UN SAB was established by H.E. Ban-Ki Moon and is the first SAB formed to provide advice to the Secretary-General of the United Nations. She discussed a Delphi study to identify global challenges that was described in the fifth report of the UN SAB, a report that additionally contains recommendations for the future of science advice in the United Nations.[76] Dr Sindi highlighted issues that scientists struggle with, how to catalyse science amongst those who will perform science in the future, and the importance of building bridges that link science to society. She asked "what does science want from government?" and answered: acceptance, as science has demonstrated great value to society as a whole. Such acceptance is a vital ingredient for successful science-policy engagement.

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

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

(b) In regard to sustainable development (specifically Sustainable Development Goal 9: "Build resilient infrastructure, promote sustainable industrialization and foster innovation"),[77] industrial biotechnology infrastructure was highlighted as having great benefits.

(c) The value of fundamental science was emphasised as an important aspect of motivating scientists and generating knowledge that can lead to applied science and scientific solutions in the future. However, the need by policy makers for applications and scientific solutions to immediate problems is often perceived to push against this.

(d) Inspiring scientists to be aspirational in their pursuit of science and mindful of the responsibility of scientists requires good communication and strong role models. The report of the UN SAB touches on some of these issues, which are useful to consider in the engagement and outreach activities of the OPCW.

(e) The SAB recognised that scientists must take a more proactive role in science communication and build bridges between science and society.

Subitem 11(c): International Criminal Court Scientific Advisory Board

11.7 Dr Eric Baccard (guest speaker, Forensic Coordinator and Head of the Forensic Science Section at the International Criminal Court (ICC)) briefed the SAB on the use of scientific evidence within the Office of the Prosecutor (OTP) of the ICC. After introducing the Court and the system of the Rome Statute, facts and figures, preliminary examinations and cases under investigation, Dr Baccard elaborated on the position of the Forensic Science Section as a component of the OTP, its mandate and its objectives, and the specific challenges met in the countries in which the OTP

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

77 For more information on the United Nations Sustainable Development Goals, see: http://www.un.org/sustainabledevelopment/.

operates. The ICC Scientific Advisory Board (ICC SAB) was formed in 2014 as an advisory body of independent experts (similar to the OPCW SAB). Dr Baccard discussed the composition, mandate, and activities of the ICC SAB, stressing the need for preservation of neutrality and objectivity (of both the Board and the Forensic Science Section of the ICC). His presentation concluded with an overview of the investigative techniques and types of scientific evidence most commonly collected.

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

(a) The SAB expressed its appreciation to Dr Baccard for his presentation focusing on the science of investigation: scientific evidence collection, methods for its analysis, and the mandate of the ICC SAB to provide independent scientific advice in support of investigative techniques (all of which are relevant to the work of the OPCW SAB and OPCW inspectors).

(b) Periodic technology surveys are highly valuable for forensic scientists, as equipment useful in both investigation and crime scene management continually come onto the market (driven by applications often unrelated to forensics). For example, 3D imaging systems can quickly and accurately create a virtual image of a location, and aerial unmanned vehicles that can be transported in a suitcase can be used on-site to quickly map a defined area. The images produced can be further analysed off-site and retrospectively, allowing continued and detailed analysis of an incident in the event that the location of interest is no longer secured or left untampered with.

(c) Another area in which forensic scientists may have expertise beneficial to OPCW inspectors is the use of technologies for ensuring chain of custody and for verifying authenticity.

(d) Data generated by mobile technologies (especially digital images and video recordings) are becoming an increasingly important source of evidence. This has necessitated the development of standardised procedures and protocols for data handling and verification of authenticity. The experiences of forensic scientists in the development of such protocols could be highly informative in understanding best practices for the use and collection of this kind of data in the context of Convention compliance investigations.

(e) The work of forensic scientists contains strong communication and engagement dimensions. Reconstructing a past event to explain in a courtroom how an incident unfolded must not only be scientifically sound, but also clearly understandable by an audience. In this regard, forensic scientists have used infographics, and 3D laser images of incident locations coupled with virtual reality equipment to great effect. These approaches, which are so valuable for explanations of investigative analysis and courtroom presentations, could be adopted for engagement and outreach opportunities and may be of potential interest to the ABEO.

12. AGENDA ITEM TWELVE – Future work of the Scientific Advisory Board

Subitems 12(a): Discussion with the Director-General

12.1 The Director-General joined the SAB to discuss ongoing work, future directions, and the importance of turning SAB recommendations into practical advice for policy-makers. He noted that the SAB had provided valuable inputs to the work of the OPCW, especially in relation to its operational work, and that significant progress had been made in engagement with States Parties (expressing gratitude for the regular briefings to the States Parties, including Science for Diplomats, by SAB members). This discourse between the SAB and States Parties is important for strengthening the Convention now and in future. He noted that the SAB had made important recommendations to the Industry Cluster through the TWG on verification, and while these were still being discussed at Industry Cluster meetings, it was important that the discourse was maintained, and that the SAB continued to make recommendations.

12.2 The Director-General expressed his concern and condemnation that chlorine had again been used as a weapon, more than 100 years after its first large-scale use. He welcomed the reaction of several chemical societies and industry associations in this regard. He requested the SAB members to encourage others in their respective fields to condemn the use of chlorine as a weapon and to spread the message for upholding the norms of the Convention.

12.3 The Director-General also encouraged SAB members to support the twentieth anniversary of the OPCW through organising events in their home countries in 2017. The Director-General pointed to the many areas of work of the OPCW in which the SAB has and continues to usefully support the Secretariat, along with new opportunities where SAB advice on scientific issues could be beneficial (to support the RRAM for example).

12.4 The SAB expressed its appreciation to the Director-General for making time to meet with the Board. The support of the SAB and its work by the Director-General, and the Board's greater interaction with States Parties, have nurtured an active scientist-policy maker engagement at the OPCW.

Subitems 12(b-e): Preparation of the Scientific Advisory Board's recommendations to the Fourth Review Conference

12.5 The SAB discussed its future work. Given the need to assess developments in S&T and make recommendations to the Director–General and the States Parties prior to the Fourth Review Conference, it is necessary to hold two SAB sessions in 2017. With the Fourth Review Conference to be held in late 2018, the SAB scheduled its next three sessions as follows:

(a) Twenty-Fifth Session: 27 – 31 March 2017;

(b) Twenty-Sixth Session: 16 – 20 October 2017; and

(c) Twenty-Seventh Session: April 2018 (dates to be confirmed).

12.6 The SAB identified thematic topics on which individual members will provide content for the report to the Fourth Review Conference. Content will be developed intersessionally and time will be devoted for review and discussion at the forthcoming sessions of the SAB. In addition to a review of developments in S&T in the five-year period from the Third to the Fourth Review Conferences, the SAB is mindful that the report to the Fourth Review Conference should provide guidance for relevant trends and issues that could usefully be monitored in the five-year period between the Fourth and Fifth Review Conferences. Proposals on how to most effectively identify relevant trends will be discussed at the SAB's Twenty-Fifth Session.

12.7 Working toward the SAB's report on developments in S&T for the Fourth Review Conference, two workshops will be held in 2017, namely:

(a) a workshop on emerging technologies with relevance to the Convention will be co-organised with the IUPAC and is expected to be scheduled for the summer of 2017. Final details are currently being discussed with the co-organisers; and

(b) a workshop on trends in industrial chemical production. Details will be forthcoming.

12.8 The SAB's report on developments in S&T is to be issued six to nine months prior to the Fourth Review Conference, so that:

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

(b) States Parties will be able to discuss S&T developments in preparation for the Review Conference; and

(c) the Secretariat will be able to take S&T advice into account when making substantive proposals to the Review Conference.

13. AGENDA ITEM THIRTEEN – Any other business

13.1 The SAB Chairperson bade farewell to Dr Abdullah Saeed Al-Amri, Dr Nicia Maria Fusaro Mourão, Professor Sławomir Neffe, and Professor Paula Vanninen, whose terms of office on the SAB will come to a close at the end of this year. He thanked all of them for their active participation and significant contributions to the SAB.

13.2 The SAB expressed its appreciation to the Netherlands Forensic Institute for hosting an informative visit that included presentations on the GIFT (Generic Integrated Forensic Toolbox to investigate CBRN incidents)[78] Project and a facility tour.

13.3 In the margins of the SAB's Twenty-Fourth Session, the SAB Chairperson and Vice-Chairperson continued to engage with the States Parties, and on 28 October they presented an overview of the activities of the SAB to representatives of the following States Parties: Australia, Bangladesh, Belgium, Bulgaria, Canada, Chile, Finland, Germany, Ghana, Guatemala, India, Ireland, Japan, Kenya, Mexico, the Netherlands,

78 For more information see: www.giftforensics.eu

Norway, Romania, Senegal, the United Kingdom of Great Britain and Northern Ireland, and the United States of America.

14. AGENDA ITEM FOURTEEN – Adoption of the report

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

15. AGENDA ITEM FIFTEEN – Closure of the session

The Chairperson closed the session at 16:55 on 28 October 2016.

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

Annex

LIST OF PARTICIPANTS IN THE TWENTY-FOURTH SESSION OF THE SCIENTIFIC ADVISORY BOARD[79]

	Participant	Institution
1.	Professor Mohammad Abdollahi	Tehran University of Medical Sciences, the Islamic Republic of Iran
2.	Dr Abdullah Saeed Al-Amri	Saudi Basic Industries Corporation, Riyadh, Saudi Arabia
3.	Professor Isel Pascual Alonso	University of Havana, Cuba
4.	Dr Veronica Borrett	BAI Scientific and Honorary Fellow, University of Melbourne, Australia
5.	Professor Flerida Arsciwals Cariño	Institute of Chemistry, University of the Philippines, Diliman Quezon City, Philippines
6.	Dr Christophe Curty	Spiez Laboratory, Switzerland
7.	Professor David González	Department of Chemistry, University of the Republic of Uruguay, Montevideo, Uruguay
8.	Dr Zrinka Kovarik	Institute for Medical Research and Occupational Health, Zagreb, Croatia
9.	Professor Roberto Martínez-Álvarez	Complutense University, Madrid, Spain
10.	Dr Robert Mikulak	United States of America Department of State
11.	Dr Nicia Maria Fusaro Mourão	Brazilian Chemical Industry, São Paulo, Brazil
12.	Professor Sławomir Neffe	Military University of Technology, Warsaw, Poland
13.	Professor Ponnadurai Ramasami	University of Mauritius
14.	Dr Syed K. Raza	Institute of Pesticide Formulation Technology (IPFT), India
15.	Mr Valentin Rubaylo	State Scientific Research Institute of Organic Chemistry and Technology, Russian Federation
16.	Mr Francois Mauritz van Straten	Chemical Weapons Working Committee, South Africa
17.	Dr Koji Takeuchi	National Institute of Advanced Industrial Science and Technology (AIST), Japan
18.	Mr Cheng Tang[80]	Office for the Disposal of Japanese Abandoned Chemical Weapons, Ministry of National Defence, China
19.	Dr Christopher Timperley[81]	Defence Science and Technology Laboratory (Dstl), Porton Down, United Kingdom of Great Britain and Northern Ireland

79 Dr Augustin Baulig was not able to attend the Twenty-Fourth Session of the SAB.

80 Vice-Chairperson of the SAB.

	Participant	Institution
20.	Professor Ferruccio Trifirò	Department of Industrial Chemistry, University of Bologna, Italy
21.	Professor Paula Vanninen	VERIFIN, Department of Chemistry, Faculty of Science, University of Helsinki, Finland
22.	Ms Farhat Waqar	Pakistan Atomic Energy Commission
23.	Professor Volodymyr Zaitsev	Taras Shevchenko National University of Kyiv, Ukraine
24.	Professor Mongia Saïd Zina	Faculty of Sciences of Tunis, Tunisia
25.	Dr Jean Armengaud (guest speaker)	French Alternative Energies and Atomic Energy Commission, Avignon, France
26.	Dr Eric Baccard (guest speaker)	International Criminal Court, The Hague, the Netherlands
27.	Dr Mirko Himmel (guest speaker)	Research Group for Biological Arms Control, University of Hamburg Centre for Science and Peace Research, Hamburg, Germany
28.	Dr Hayat Sindi (guest speaker)	United Nations Scientific Advisory Board
29.	Dr Jean-Pascal Zanders (guest speaker)	OPCW Advisory Board on Education and Outreach

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[81] Chairperson of the SAB.