Thirty-Ninth Session
1 – 4 April 2025

SAB-39/1
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REPORT OF THE SCIENTIFIC ADVISORY BOARD AT ITS THIRTY-NINTH SESSION

1. AGENDA ITEM ONE – Opening of the session

1.1 The Scientific Advisory Board (SAB) met for its Thirty-Ninth Session from 1 to 4 April 2025. The session was chaired by Prof. Imee Su Martinez, with Prof. Elisa Souza Orth serving as Vice-Chairperson.

1.2 Prof. Martinez opened the Thirty-Ninth Session of the SAB by referring to the discussions at the Twenty-Ninth Session of the Conference of the States Parties (the Conference) regarding the need to increase the representation of women within the Technical Secretariat (the Secretariat) and the SAB. She informed the Board that, for the first time in its history, both the Chairperson and Vice-Chairperson were women. Additionally, she noted that the Chairpersons of both current temporary working groups (TWGs) were also women.

1.3 Prof. Martinez welcomed all Board members, external speakers, and especially the four new members who had joined the Board in January 2025. She acknowledged the seven SAB members who would depart the Board at the end of 2025 and thanked them for their hard work and commitment. Prof. Martinez also thanked the Secretary to the SAB and his colleagues in the Secretariat for their guidance and assistance, both in preparations for and during this session. Finally, she extended her gratitude to Mexico and the Philippines for their recent voluntary contributions to the SAB Trust Fund.

1.4 In closing, the Chairperson reminded the SAB of the importance of science and recalled an apt quote from the recent meeting of the United Nations Educational, Scientific and Cultural Organization (UNESCO) on “Science Diplomacy in a Rapidly Changing World: Building Peace in the Minds of Men and Women”, stating that “science is not just an academic exercise, but it is a lifeline for a rapidly changing world”.

Executive summary

1.5 The Board met in person at the OPCW Main Building; those members unable to travel were able to participate virtually via the Organisation’s videoconferencing equipment.

1.6 The SAB received briefings from 10 external speakers on topics including research in the chemical and biological fields, decontamination, imaging, sensing, detection, and analysis. The Board also heard from staff members of the Secretariat, and received updates from both the Secretary to the SAB and the OPCW Laboratory. An update on OPCW activities in the Syrian Arab Republic and Ukraine was also provided by the Office of the Director-General. The Chairpersons of the TWGs on Chemical Forensics and on Artificial Intelligence (AI) updated the Board on the mandates of their respective Groups and the progress to date. The SAB also dedicated one session to discussing its approach to the Sixth Review Conference.[1]

1.7 Based on deliberations at its Thirty-Ninth Session, the Board recommends to the Director-General through this report that:

(a) in preparation for the next Review Conference, consideration be given to holding workshops on the following topics:

(i) simple, reliable, and low-cost sensing/detection systems, which would have relevance for and utility in States Parties with developing economies;

(ii) medical preparedness for incidents involving exposure to toxic chemicals, including hospitals and on-site medical response and management;

(iii) science and technology relevant to central nervous system-acting chemicals;

(iv) technical information related to the chemicals that were added in 2019 to the Annex on Chemicals to the Chemical Weapons Convention (the Annex on Chemicals);[2]

(v) scientific and technical information pertaining to chemical warfare agents, their precursors, and other toxic chemicals, in order to provide a scientific underpinning for ongoing discussions related to adaptations to the Annex on Chemicals, and associated activities, such as declaration thresholds;

(vi) chemical warfare agent destruction and abatement technologies, particularly those that are portable and/or can effectively handle small amounts of materials; and

(vii) diagnosis and treatment of biotoxin exposure, involving clinicians and veterinarians with relevant experience. Not only would early clinical diagnosis assist in identification of the agent used, but compilation and further dissemination of information on diagnosis and treatment of biotoxin casualties would contribute to the efforts of the OPCW on assistance and protection. This recommendation reiterates the first recommendation from the end-of-mandate report from the TWG on the Analysis of Biotoxins;

(b) the Secretariat consider convening a follow-up workshop to the one held last year on deployable equipment. This follow-up workshop would focus on the performance and robustness of novel, off-the-shelf instrumentation for on-site detection and chemical analysis; and

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1 Review Conference = Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention.

2 The Board notes that since the addition of these chemicals, the availability of information published in the scientific literature has increased and there is value in compiling this information to identify remaining gaps.

(c) the Secretariat continue efforts to strengthen its human resources related to science and technology. In particular, the recruitment of additional personnel with expertise in emerging technologies relevant to the Chemical Weapons Convention (the Convention) would be beneficial.

1.8 In addition to the aforementioned recommendations, the Board stands ready to provide scientific advice, as needed, during the foreseen missions by the OPCW to assist the Syrian Arab Republic in meeting its obligations under the Convention. This may include, but is not limited to, scientific and technical questions related to in-field detection technologies, and small-scale and/or modular destruction systems and technologies.

2. AGENDA ITEM TWO – Welcome address by H.E. Ambassador Fernando Arias

2.1 The Director-General, H.E. Ambassador Fernando Arias, welcomed the attendees to the Thirty-Ninth Session of the SAB and acknowledged in particular the four new members joining the Board.

2.2 The Director-General commenced his address by focusing on AI. He recalled the success of the first Global Conference on the Role of Artificial Intelligence in Advancing the Implementation of the Chemical Weapons Convention (the Global Conference), which was co-hosted by Morocco and the OPCW in October 2024. Following a recommendation from the SAB at its Thirty-Eighth Session, the Director-General established a new TWG on AI, which began its mandate on 1 January 2025. Additionally, he reported that the TWG on Chemical Forensics had convened four times and was progressing well, with its end-of-mandate report expected in early 2026.

2.3 While AI remains a priority for the OPCW, the Director-General encouraged the Board to maintain a broad perspective. He outlined several topics for ongoing focus, including synthetic biology, industrial biotechnology, 3D printing, laboratory automation, and drone technology. The Director-General also addressed recent developments in the Syrian Arab Republic, emphasising the scientific and technical aspects of the role of the Organisation in verifying the Syrian declarations and overseeing the destruction of any remaining chemical weapons. He noted that more than 100 sites will need to be visited by the OPCW in the coming months, and while the amount of chemical weapons to be destroyed is far less than in the operation conducted 11 years ago, the work this time is much more difficult in scope. He requested that SAB members remain prepared to provide expert scientific advice as developments unfold.

2.4 In closing, the Director-General expressed his sincere gratitude for the valuable contributions of Board members throughout the year. He acknowledged their participation in the equipment workshop hosted by the Inspectorate Division last December and their role in technical evaluation committees, such as for the OPCW AI Research Challenge, ensuring a rigorous and impartial selection process.

3. AGENDA ITEM THREE – Adoption of the agenda

The SAB adopted the following agenda for its Thirty-Ninth Session:

1. Opening of the session
2. Welcome address by H.E. Ambassador Fernando Arias
3. Adoption of the agenda
4. *Tour de table*
5. Establishment of a drafting committee
6. Update on the activities of the Technical Secretariat and the SAB
7. Update on the SAB Temporary Working Group on Chemical Forensics
8. Update on the SAB Temporary Working Group on Artificial Intelligence
9. Update on the activities at the OPCW Laboratory
10. Update and discussion on the activities in the Syrian Arab Republic and Ukraine
11. Decontamination and direct analysis: Field and laboratory perspectives
12. Chem-bio research at TNO: An overview
13. Using Makerspaces and DIYbio laboratories for small-scale automation
14. Seeing the invisible: Flow visualisation and scientific imaging to improve CBRNE safety, security, defence, and forensics
15. Rapid chemical sensing for olfactory navigation
16. Drone-based localisation of hazardous chemicals by passive smart dust
17. Fluorescent and colorimetric detection of chemical warfare agents: A journey towards accurate detection and differentiation
18. Miniaturised printed electrochemical biosensors for smart detection of chemical and biological warfare agents
19. Pesticides: Analyses and treatment
20. SAB discussion on its approach to the Sixth Review Conference
21. SAB Chairperson and Vice-Chairperson election
22. SAB discussion on conferences, meetings, and publications
23. Any other business
24. Closing remarks
25. Adoption of the report
26. Closure of the session

4. AGENDA ITEM FOUR – *Tour de table*

All participants in the session were invited to introduce themselves to their colleagues. A list of participants appears in Annex 1 to this report.

5. AGENDA ITEM FIVE – Establishment of a drafting committee

The Chairperson asked volunteers who wished to be part of the drafting committee to prepare the report of the SAB at its Thirty-Ninth Session to notify the Chairperson, Vice-Chairperson, or Secretary.

6. AGENDA ITEM SIX – Update on the activities of the Technical Secretariat and the SAB

6.1 The Secretary to the SAB provided the Board with an update of relevant activities from the intersessional period. He began by providing a brief overview of OPCW activities, highlighting the Twenty-Ninth Session of the Conference of the States Parties (at which the Chairperson of the SAB provided an update to States Parties), the Secretariat's assistance to Ukraine via several technical assistance visits, and the renewed opportunities in the Syrian Arab Republic following the change in leadership.

6.2 The Secretary to the SAB then provided an update on the various initiatives of the Secretariat related to AI since the last session of the SAB, focusing principally on the Global Conference and the OPCW AI Research Challenge. He noted the primary focus areas of the Global Conference and presented the key outcomes, emphasising its success and the valuable insights gained. Building on the details shared at the Thirty-Eighth Session of the SAB, the Secretary updated the Board on the outcome of the call for proposals for the AI Research Challenge, and briefly described each of the four funded projects. He concluded this segment on AI by introducing the new TWG on AI, which was established in response to a SAB recommendation and started its one-year mandate on 1 January 2025.

6.3 There will be a number of pertinent and interesting scientific conferences in 2025 and early 2026. The Secretary provided an overview of some of these,[3] highlighting themes of interest.

6.4 The Secretary to the SAB subsequently turned his focus to the preparation of the SAB report on developments in science and technology for the Sixth Review Conference. He noted that time would be made available for an in-depth discussion on the last day of the session, and strongly encouraged all SAB members to be ready to contribute their ideas.

6.5 After providing several key reminders for the Board, the Secretary to the SAB concluded his update by informing the Board of the two recent contributions to the SAB Trust Fund from Mexico and the Philippines.

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3 IUPAC World Chemistry Congress 2025 in Kuala Lumpur, Malaysia, from 14 to 19 July 2025 (https://iupac.org/event/iupac-world-chemistry-congress-2025/); ACS Fall 2025 in Washington, DC, United States of America, from 17 to 21 August 2025 (https://www.acs.org/events/fall.html); the 15th CBRNe Protection Symposium and the Exhibition of CBRNe Protection Equipment in Malmö, Sweden, from 30 September to 2 October 2025 (https://www.cbrnesymposium.se/); and the 7th CBRNE Research & Innovation Conference in Arcachon, France, from 19 to 21 May 2026 (https://cbrneconference.fr/).

7. AGENDA ITEM SEVEN – Update on the SAB Temporary Working Group on Chemical Forensics

7.1 Dr Anne Bossée, Chairperson of the TWG on Chemical Forensics, provided an update on the work of the Group since the last session of the SAB. She began her presentation by outlining the objectives and composition of the TWG, highlighting its four principal technical focus areas, each managed by a dedicated subgroup. She then provided a timeline of the two-year mandate of the TWG, and noted that four out of six planned meetings had already taken place.[4] The TWG Chairperson remarked that numerous external speakers have addressed the Group at these four meetings, underscoring the breadth of topics considered and knowledge shared.

7.2 Dr Bossée provided a sequential update on the principal findings of each of the four subgroups, highlighting the key challenges encountered. These include the limited availability of reference data, restrictions preventing designated laboratories from using internet-hosted AI tools in sensitive information technology environments, and a lack of experience among chemical analysts in utilising these tools, among other issues. The findings of two literature reviews were also highlighted.

7.3 In closing, Dr Bossée noted that at the fifth meeting of the TWG in June, the recommendations currently being developed by the subgroups will be further refined. The Group will also agree upon the structure and format of its end-of-mandate report; a glossary of terms has already been created to enhance readability. The TWG aims to complete its report by the end of December 2025, allowing the SAB time to consider it at its next session.

7.4 Members of the SAB raised questions about the adoption of AI tools in chemical forensics and the associated challenges, the potential presentation of these tools in court, and approaches to developing a database containing information relevant to the forensic analysis of chemical warfare agents.

8. AGENDA ITEM EIGHT – Update on the SAB Temporary Working Group on Artificial Intelligence

8.1 Dr Catharina Müller-Buschbaum, Chairperson of the TWG on AI, provided an introductory overview to the work of the Group, which started on 1 January 2025. She described the foundational work that had been carried out by the Secretariat and the SAB prior to establishment of the TWG by the Director-General. Dr Müller-Buschbaum subsequently set out the objectives, composition, and terms of reference of the TWG (listed in full in Annex 2 to this report), and the division of its work into four subgroups.

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4 SAB-38/WP.1, dated 15 May 2024; SAB-39/WP.1, dated 21 August 2024; SAB-39/WP.2, dated 16 January 2025, and Corr.1, dated 27 January 2025; and SAB-39/WP.3, dated 25 March 2025. Note that the terms of reference and the specific work of the subgroups are described in SAB-38/WP.1.

8.2 Given the novelty of AI, its unprecedented pace of development, and its rapid inclusion in many fields, the objectives of the TWG are to understand the impact of AI on the object and purpose of the Convention, and to identify the risks to and opportunities for its implementation. These objectives will be met through a detailed review of current AI capabilities and technology adoption. In light of the ongoing developments in this field, this TWG has a one-year mandate. Dr Müller-Buschbaum informed the Board that three plenary meetings are planned throughout the year, the first of which will take place from 9 to 11 April 2025. Additionally, there will be a series of virtual meetings for the subgroups, and biweekly meetings to address advances in this fast-moving field.

8.3 The terms of reference of the TWG on AI set out specific questions relating to six technical areas to be considered by the Group, namely:

(a) synthesis and retrosynthesis prediction;

(b) automated and remote synthesis and production of chemicals;

(c) data curation, protection, and reliability;

(d) property, spectral, and data prediction and generation;

(e) data/sensor fusion for augmented detection and analysis; and

(f) simulation and training.

8.4 The Group has divided into four subgroups, according to the expertise and interests of the members, to consider these technical areas. Additionally, the Group will collectively examine six further questions—covering topics such as indicators of misuse, responsible use, and governance—while also identifying any other relevant AI applications within the scope of its work.

8.5 At the end of its mandate, the TWG will provide a list of recommended short- and long-term actions to ensure that AI can be harnessed for good, and that its associated risks can be mitigated or, at a minimum, closely monitored. Its findings and recommendations will be considered by the SAB and the Director-General.

8.6 In response to a question from the Board, Dr Müller-Buschbaum highlighted how large language models can generate synthesis routes for specific chemicals, which can then be produced using automated equipment and robotics, thus demonstrating that the entire end-to-end synthesis process can be completed without human intervention.

9. AGENDA ITEM NINE – Update on the activities at the OPCW Laboratory

9.1 Mr Adriaan Marais, a Senior Analytical Chemist at the OPCW Laboratory, opened his presentation with a brief overview of the key tasks undertaken at the Laboratory, namely providing support for sampling and analysis, maintaining accreditation to International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) Standards 17025 and 17043, and providing capacity-building training courses to States Parties.

9.2 In terms of supporting sampling and analysis, the OPCW Laboratory maintains the network of OPCW designated laboratories. Mr Marais described the two types of designated laboratories: one for environmental samples, and the other for biomedical samples. He reported that as of November 2024, there were 30 designated laboratories in 25 States Parties for the analysis of environmental samples, and 18 designated laboratories in 14 States Parties for the analysis of biomedical samples.

9.3 Citing examples such as the Syrian Arab Republic, Salisbury, and Ukraine, Mr Marais noted that designated laboratories have conducted analyses with increasing frequency since 2013. He also recalled the three ongoing non-routine missions: the Declaration Assessment Team, the OPCW Fact-Finding Mission in Syria, and the Investigation and Identification Team. In this context, he emphasised the importance of ensuring that proficiency tests adequately reflect real-life requirements.

9.4 Mr Marais outlined the proficiency test process used to assess the competencies of the designated laboratories on an annual basis. He informed the Board that the First Trial OPCW Biotoxins Proficiency Test was successfully conducted in 2024, and efforts are under way to implement the second test later this year. Mr Marais recalled that, between 2015 and 2023, an optional non-scoring sample for chemical forensics analysis was routinely included with environmental proficiency test samples. This approach demonstrated improvements in the chemical forensics capabilities of the participating laboratories. However, Mr Marais noted that from 2020 onwards, participation in this optional analysis declined until it was no longer considered viable, partly due to the COVID-19 pandemic and other factors.

9.5 The OPCW Laboratory recently distributed a questionnaire to designated laboratories to benchmark existing chemical forensic analysis capabilities, assess interest in future chemical forensics exercises, and gain insights into current approaches and perspectives on chemical forensics.

9.6 To ensure that designated laboratories are fit for purpose in terms of chemical forensics, Mr Marais noted that four key areas have been identified for technical development: reporting and probabilistic interpretation; statistical processing and feature comparison; data processing methods and quality control; and semi-quantitative analysis and measurement uncertainty. To support this development, a “dry” (data-based) laboratory exercise is currently drawing to a close and a “wet” (laboratory-based) exercise, called Icarus, is planned for the near future. Icarus is a sample-matching exercise designed to simulate real-world conditions with realistic forensic questions.

9.7 Mr Marais closed his presentation with an update on the microsynthesis facility, which is now operational and able to produce non-scheduled chemicals, and on quality assessment audits that had been successfully completed in May 2024 to ensure that the OPCW Laboratory remains accredited.

9.8 In the ensuing discussion with the Board, Mr Marais provided further details on the types of chemicals that are included in proficiency test samples; he confirmed that this could include biotoxins as well as the chemicals recently added to the Schedules of chemicals. The reasons for differences in the data contained in the OPCW Central Analytical Database (OCAD) and other similar databases were explored, and the merits of expanding the OCAD to create a database for chemical forensics were debated. In addition to answering questions on metabolomics, equipment sensitivity limits, and detection equipment, Mr Marais explained why collaborations between organic and analytical chemists will be invaluable for chemical forensics of chemical warfare agents.

10. AGENDA ITEM TEN – Update and discussion on the activities in the Syrian Arab Republic and Ukraine

10.1 Mr Sébastien Braha, Chief of Cabinet in the Office of the Director-General, opened his briefing with an overview of the developments concerning the Syrian Arab Republic and the Secretariat's activities since the change of government in December 2024. He underscored that the interim authorities in the Syrian Arab Republic are committed to the goals and principles of the Convention and fully support the work of the Secretariat to:

(a) resolve the outstanding gaps and inconsistencies in the declaration of the Syrian chemical weapons programme, ensuring that the declaration is accurate and complete; and

(b) ensure that investigations led by the Secretariat on the use of chemical weapons in the Syrian Arab Republic can be completed.

10.2 Despite this commitment, Mr Braha explained that the task ahead remains particularly challenging and complex. This is partly due to a lack of capacity to access some of the necessary information by the interim authorities, compounded by security concerns arising from the ongoing instability in the country. Mr Braha noted that the activities of the Secretariat are further complicated by the large number of sites—in excess of 100—to be visited, in addition to the availability of financial, logistical, security, and human resources. He informed the Board that the Secretariat is working closely with the interim Syrian Government to continue the implementation of the OPCW Nine-Point Action Plan.[5] Mr Braha recognised that any delays may increase proliferation risks, and noted that it is the responsibility of States Parties to ensure, through adequate support, the avoidance of such delays.

10.3 Mr Braha also provided a very brief update on the activities of the Secretariat concerning Ukraine. He outlined the Ukrainian request for assistance and the subsequent provision of detection and protection equipment and related training, funded by voluntary contributions from States Parties. Mr Braha described the two technical assistance visits following incidents of alleged use of toxic chemicals as a weapon, and noted that the next steps would be decided by Ukraine and States Parties.

10.4 The Board members posed a series of questions focusing exclusively on the Syrian Arab Republic. They acknowledged the challenging situation and the significant time pressure, and discussed how the OPCW will ensure that it has access to the expertise needed, the likely timescales required to implement the OPCW Nine-Point Action Plan, the chemical forensics approach that will be adopted, and the types of agents that may have been produced.

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5 For more information on the OPCW Nine-Point Action Plan, see: https://www.opcw.org/sites/default/files/documents/2025/02/NV%20651%20PR%20Qatar%20-%2022-1-2025.pdf.

11. AGENDA ITEM ELEVEN – Decontamination and direct analysis: Field and laboratory perspectives

11.1 During her presentation to the Board, Dr Pernilla Lindén, from the Swedish Defence Research Agency (FOI), focused on the results of two recent publications. The first publication examined the effectiveness of various decontamination agents in breaking down fentanyl and carfentanil.[6] Dr Lindén explained that between 2016 and 2017, Sweden experienced a wave of fentanyl-related deaths, and while cases have since declined, they continue yearly. Fentanyl, a potent synthetic opioid, is ~100 times stronger than heroin, while carfentanil—used to sedate large animals—is ~10,000 times stronger.

11.2 The FOI has ongoing research focused on identifying a safe, easy, and low-cost method to decontaminate surfaces from fentanyl. This research started with an initial screening study to determine the degradation efficiencies of several commercial decontamination agents for fentanyl and carfentanil, in addition to readily available decontaminants such as bleach and hydrogen peroxide found in common domestic cleaning products. The degradation products were subsequently identified using high-resolution mass spectrometry (HRMS). Studies on the potency and metabolism of the most common degradation products (the *N*-oxide analogues of fentanyl and carfentanil) revealed that while *N*-oxides are metabolised more slowly than the intact drugs, their effects on the opioid receptor in the body is 120 times lower, making these degradation products safer than the intact drugs.

11.3 In the subsequent surface decontamination studies, Dahlgren Decon—a commercial decontaminant which exhibited a high degradation efficiency in the screening study—and two bleach-containing domestic cleaning sprays were investigated. Dahlgren Decon continued to show a high degradation efficiency, while the efficiency of the cleaning sprays could not be determined because they cause agglomeration. Consequently, analysis of surface extracts by liquid chromatography-mass spectrometry (LC-MS) was unreliable.

11.4 Dr Lindén introduced a technique newly adopted by her team: direct analysis in real time (DART), combined with HRMS. This analytical technique has several benefits over traditional techniques, including the speed of analysis, low cost, ease of use, small footprint, and robust nature. DART-HRMS was applied to the aforementioned surface decontamination studies and, through very fast analysis, showed that water (positive control) and the cleaning sprays had minimal effect on the contaminated surface; it also confirmed the high efficacy of Dahlgren Decon.

11.5 The research from the second publication also leveraged DART and focused on riot control agents.[7] The aim of the work was to determine whether DART could be adapted for analysis in the field, and riot control agents were selected due to their ready availability. Dr Lindén stressed the importance of developing a single DART method that could be used to detect all 16 chemicals in the study, and noted that this could be

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6 Lindén, P., L. Mörén, J. Qvarnström, N. Forsgren, C. Springer Engdahl, M. Engqvist, J. Henych, et al. "Field and Laboratory Perspectives on Fentanyl and Carfentanil Decontamination." *Scientific Reports* 14, no. 1 (October 25, 2024). https://doi.org/10.1038/s41598-024-74594-z.

7 Mörén, L., A. Östin, A. Larsson, J. Forsberg, D. Wiktelius, and P. Lindén. "Rapid Screening of Riot Control Agents Using DART-TD-HRMS." *Forensic Toxicology* 42, no. 2 (February 22, 2024): 152–62. https://doi.org/10.1007/s11419-024-00681-5.

achieved using DART coupled with thermal desorption (TD) HRMS (DART-TD-HRMS). This method was then tested against an in-house library of commercial self-defence sprays, and demonstrated that both the active substance and trace substances in all 27 available sprays could be correctly identified. In the final part of this study, DART-TD-HRMS was used to screen fabric swatches contaminated with riot control agents, as this was considered to be a more realistic application of the technique in the field. The swatches were tested one hour after spraying, and then weekly for three weeks. Despite being stored in a fume cupboard with constant air flow over the swatch surfaces, the riot control agents could still be detected after three weeks.

11.6 Dr Lindén's presentation generated much discussion among the SAB members, and questions on several key themes were raised. First, various SAB members enquired about the mechanistic pathways in the degradation process and the mass ratio of decontaminant to drug in order to understand whether the process is catalytic or stoichiometric. Some additional decontaminants and approaches, such as adding manganese to hydrogen peroxide, were also proposed by the Board. The types of surfaces used in the study and the decontamination time were also discussed. A question was also asked about the performance of DART compared to established field detection techniques like Raman spectroscopy. Dr Lindén noted her interest in comparing the instruments, which is planned as future work at the FOI. Finally, the use of high-throughput methods and automation was proposed to reduce human variability in experimentation and allow for more samples and parameters to be explored.

12. AGENDA ITEM TWELVE – Chem-bio research at TNO: An overview

12.1 Dr Ruud Busker from the Netherlands Organisation for Applied Scientific Research (TNO) delivered the first part of this joint presentation, beginning with a brief overview of his organisation's structure and noting that it operates in various areas of societal concern, including defence and security. Dr Busker works in the Chemical, Biological, Radiological, and Nuclear (CBRN) Protection Department, which he noted is relatively small with approximately 50 staff. CBRN-related research at TNO spans four principal areas: development, testing and evaluation, low technology readiness level research, and task- and capability-related research. He indicated that the OPCW designated laboratory in the Netherlands falls into the last category. After this introduction, Dr Busker provided a series of examples of CBRN-related projects that have been implemented at TNO.

12.2 One of the key examples that Dr Busker presented was the development of a civil-military reconnaissance vehicle equipped with various detection technologies, including ion mobility spectrometry-based detectors, photoionisation detectors, Raman spectroscopy, and infrared sensors. The vehicle is designed to detect toxic chemical vapours and aerosols while ensuring the safety of personnel inside. To validate the detection and protection capabilities of the vehicle, tests were conducted using an ambient breeze tunnel. This set-up allowed researchers to expose the vehicle to controlled vapour and aerosol challenges of simulants, comparing its detector responses with reference detectors. Additionally, safety experiments measured aerosol concentrations inside and outside the vehicle, demonstrating its ability to protect personnel. These results provided confidence in the vehicle's operational effectiveness.

12.3 Dr Busker also introduced the Chemical Hot Aerosol Research Tool (CHART), a system for studying the effects of toxic chemical aerosols.[8] This tool enables researchers to generate and characterise aerosols of simulants, study their stability, and assess the effectiveness of protective fabrics and detectors.

12.4 Another significant area of research discussed was the detection of exposure to chemical warfare agents through the analysis of biomarkers. TNO has developed methods to detect the adducts of nerve agents and sulfur mustard with proteins in the blood, enabling the verification of exposure.[9,10]

12.5 The first part of the presentation concluded with an overview of the work by TNO in the field of biological defence, including the development of a diagnostic method combining CRISPR-Cas[11] technology with loop-mediated isothermal amplification (LAMP) for detecting pathogens. This work aims to achieve the sensitivity of polymerase chain reaction (PCR) approaches with the ease and speed of immunological tests.

12.6 The second part of the presentation was given by Dr Mirjam de Bruin-Hoegée, who provided more detailed technical insights into research on decontamination, medical countermeasures, chemical forensics, and operational toxicology at TNO. She highlighted that these are extensive research areas and, given the small size of the CBRN Protection Department, cross-TNO collaborations are leveraged to effectively carry out the work.

12.7 Dr de Bruin-Hoegée described a decontamination project which explored the effectiveness of commercial decontamination kits on fentanyl-contaminated surfaces and skin.[12] The research showed that while these kits removed a significant amount of fentanyl, they did not degrade the compound. The study also highlighted the transfer of fentanyl from contaminated surfaces to skin, emphasising the importance of decontamination for first responders.[13] Recently, this research had also been extended

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8 Durán Jiménez, D., T. Venema, M. de Bruin-Hoegée, D. P. Alkema, R. W. Busker, and A. L. van Wuijckhuijse. "CHART: A Novel System for Detector Evaluation against Toxic Chemical Aerosols." *Scientific Reports* 14, no. 1 (January 10, 2024). https://doi.org/10.1038/s41598-023-50718-9.

9 Noort, D., A. Fidder, D. van der Riet-van Oeveren, R. Busker, and M. J. van der Schans. "Verification of Exposure to Novichok Nerve Agents Utilizing a Semitargeted Human Butyrylcholinesterase Nonapeptide Assay." *Chemical Research in Toxicology* 34, no. 8 (July 13, 2021): 1926–32. https://doi.org/10.1021/acs.chemrestox.1c00198.

10 Hemme, M., A. Fidder, D. van der Riet-van Oeveren, M. J. van der Schans, and D. Noort. "Mass Spectrometric Analysis of Adducts of Sulfur Mustard Analogues to Human Plasma Proteins: Approach towards Chemical Provenancing in Biomedical Samples." *Analytical and Bioanalytical Chemistry* 413, no. 15 (April 26, 2021): 4023–36. https://doi.org/10.1007/s00216-021-03354-z.

11 Clustered regularly interspaced short palindromic repeats–CRISPR-associated proteins

12 Verheij, E. R, M. J Joosen, L. Cochrane, M. de Bruin-Hoegée, and M. C de Koning. "Decontamination of Toxic Industrial Chemicals and Fentanyl by Application of the RSDL® Kit." *Journal of Special Operations Medicine* 20, no. 1 (2020): 55. https://doi.org/10.55460/cofj-wmpa.

13 de Bruin-Hoegée, M., M. C. de Koning, L. Cochrane, and M. J.A. Joosen. "Contact Transfer Risk from Fentanyl-Contaminated RSDL® Kit." *Toxicology Letters* 319 (February 2020): 237–41. https://doi.org/10.1016/j.toxlet.2019.11.013.

to include three of the recently scheduled nerve agents, and the kit was found to be highly effective in preventing intoxication.[14]

12.8 Concerning medical countermeasures, Dr de Bruin-Hoegée detailed research into the development of methods to diagnose intoxication based on signs and symptoms, rather than specific chemical reactions in the body. This approach aims to make diagnosis easier and more accessible in the field. The research also included the development of a small animal model to screen for therapeutic antidotes against fentanyl compounds.

12.9 Fentanyl and its analogues have also been the focus of chemical forensics research at TNO, and Dr de Bruin-Hoegée presented research on identifying synthesis-specific markers after incubating samples of these compounds with liver microsomes to mimic human metabolism.[15] The study aimed to determine the synthesis method used for fentanyl found in forensic cases. The research involved synthesising fentanyl and its analogues in various ways, analysing the samples before and after metabolism, and applying chemometrics to distinguish between different synthesis routes based on impurities derived from both metabolised and non-metabolised impurities.

12.10 Finally, research on operational toxicology was briefly presented and focused on the risks associated with exposure to various chemicals in military and first responder environments, such as benzene and chromium(VI). The research included toxicity screening of the operational environment and the development of sensors for on-body detection of toxic compounds.

12.11 The presentation elicited many questions for both speakers from Board members, primarily on fentanyl-based research, the civil-military reconnaissance vehicle, and the CHART system. Dr de Bruin-Hoegée noted that the fentanils used in the research were synthesised in-house due to difficulties procuring commercial samples. She further clarified that only fentanyl, in addition to some toxic industrial chemicals, was used in the skin penetration test. She provided additional details relating to the origin of the impurities in the chemical profiles of the fentanils, and noted the difference in terms of speed and complexity between in vitro microsomal metabolism and human metabolism. Regarding the civil-military reconnaissance vehicle, Dr Busker explained that it had been tested against a challenge of simulants in the ambient breeze tunnel and is fitted with a range of detection devices, similar to those used by OPCW inspectors during a mission. He confirmed that both liquid and solid aerosols may be generated in the CHART system utilising electrospray technology.

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14 Cornelissen, A. S., R. M. van den Berg, J. P. Langenberg, M. van Grol, R. Bross, J. Pittman, L. Cochrane, and V. Savransky. “Effective Skin Decontamination with RSDL® (Reactive Skin Decontamination Lotion Kit) Following Dermal Exposure to a Novichok Class Nerve Agent.” *Chemico-Biological Interactions* 395 (May 2024): 111001. https://doi.org/10.1016/j.cbi.2024.111001.

15 de Bruin-Hoegée, M., D. Kleiweg, D. Noort, and A. C. van Asten. “Chemical Attribution of Fentanyl: The Effect of Human Metabolism.” *Forensic Chemistry* 24 (June 2021): 100330. https://doi.org/10.1016/j.forc.2021.100330.

13. AGENDA ITEM THIRTEEN – Using Makerspaces and DIYbio laboratories for small-scale automation

13.1 During her presentation, Prof. Nadya Peek from the University of Washington, United States of America, discussed advances in digital fabrication and its implications for both research and industry.

13.2 Prof. Peek explained that custom manufacturing is now more accessible than ever, thanks to community spaces like Makerspaces.[16] She compared Makerspaces to libraries, where, instead of accessing books, visitors can access a range of tools like 3D printers, computer-controlled mills, and laser cutters. She highlighted the 3D printing hype cycle, which peaked in the 2010s with the release of small desktop printers, though 3D printing itself has been around since the 1970s. The expiration of patents in 2002 led to a rapid proliferation of 3D printers and other computer-controlled machines in the 2010s, sparking the “maker movement” and the idea of “personal fabrication”. This has opened up new possibilities for people to make almost anything. The availability of accessible computer-aided design (CAD) software, now often free or at a low cost as long as designs are made public, has played a key role in lowering barriers to entry. Prof. Peek also described DIYbio laboratories,[17] also comparing them to libraries, but with access to biological equipment instead of books. She noted that although biological equipment such as PCR machines and incubators are available, the order of experimentation and the time required may increase barriers to entry compared to Makerspaces.

13.3 Beyond individual projects, digital fabrication techniques are also being employed to develop new machines and tools. The ability to design and produce additional fabrication equipment facilitates replication, customisation, and expansion of technological capabilities. Prof. Peek’s laboratory has focused on creating toolkits and machines that empower end users, with one notable example being Jubilee: a motion platform with automated tool changing.[18] Jubilee is designed with modularity in mind, using easy-to-source parts, many of which are 3D printed. This approach aligns with Prof. Peek’s interest in open-source hardware, particularly in the realm of electro-mechanical devices such as robot arms and laboratory instruments like liquid handlers.

13.4 Jubilee has gained traction among scientists for laboratory automation, largely due to its extensive documentation and strong community support.[19] Prof. Peek emphasised that adoption is driven not only by its open-source nature but also by understanding scientists’ needs and workflows. To enhance usability, her team has developed computational notebook-based interfaces that integrate machine control, data collection, and analysis. These interfaces enable iterative workflow development with closed-loop control, including Bayesian optimisation, to automate multistep processes. In addition, Prof. Peek

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16 For more information, see: https://makerspace.com/.

17 For more information, see: https://diybio.org/.

18 Vasquez, J., H. Twigg-Smith, J. Tran O’Leary, and N. Peek. “Jubilee: An Extensible Machine for Multi-Tool Fabrication.” *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, April 21, 2020, 1–13. https://doi.org/10.1145/3313831.3376425.

19 Dunn, K., C. Feng, and N. Peek. “Jubilee: A Case Study of Distributed Manufacturing in an Open Source Hardware Project.” *Journal of Open Hardware* 7, no. 1 (2023). https://doi.org/10.5334/joh.51.

noted that many tools in her laboratory are modular, allowing for the creation of custom tools tailored to specific needs. For example, Popfab, a modular system that folds into a briefcase, can switch between functions like 3D printing and pipetting, demonstrating how digital fabrication can facilitate versatile, low-cost laboratory tools.

13.5 This work contributes to the broader concept of self-driving laboratories (SDLs), which leverage automation and modular design to support diverse scientific applications.[20] Prof. Peek highlighted the advantages of open-source, customisable, and cost-effective SDLs, particularly in education and research. However, she also discussed competing approaches such as cloud laboratories and mobile laboratory robots, which prioritise high throughput over adaptability. While these innovations hold promise, she stressed the importance of balancing efficiency with the flexibility needed to develop new experimental workflows.

13.6 During the question-and-answer session, a concern was raised about the potential risks of digital fabrication technologies from a chemical security perspective. It was noted that such tools could be misused by malicious actors, who are often inventive in repurposing technology for harmful purposes. The dual-use nature of these tools was emphasised, as they can be applied in both beneficial and harmful ways.

13.7 Another point discussed was the importance of fostering diversity of thought within the scientific community. Encouraging synthetic chemists to embrace digital fabrication, and those working in digital fabrication to think about synthetic chemistry needs was seen as key to unlocking the full potential of this technology. With programming becoming more accessible and undergraduates acquiring computational skills, there is a growing opportunity to explore innovative approaches to chemistry. While there may be upfront costs associated with learning new computational skills, the long-term benefits are clear, as these skills are expected to pay off in future research and development.

14. AGENDA ITEM FOURTEEN – Seeing the invisible: Flow visualisation and scientific imaging to improve CBRNE safety, security, defence, and forensics

14.1 Dr Matthew Staymates, from the National Institute of Standards and Technology (NIST), United States of America, provided the Board with an overview of his work on flow visualisation and illustrated his presentation with a number of videos showing the technique in action. He opened his presentation by explaining that over the past two decades, the NIST has built a fundamental metrology, research, and standards infrastructure that supports the optimisation of chemical, biological, radiological, nuclear, and explosive (CBRNE) sampling and detection technologies, and assists in the development of next-generation technologies. Dr Staymates then provided a brief overview of the NIST programme in trace detection and forensic chemistry, emphasising how flow visualisation and scientific imaging tools play a key role in the success of these areas. Underscoring their importance, he explained that these tools are used to identify sampling inefficiencies and help guide the optimisation process for improved processing and sampling. These unique visualisation tools may be beneficial to the CBRNE community and help optimise next-generation environmental sampling and detection systems.

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[20] Pelkie, B., S. Baird, E. Aissi, K. Aspuru-Takata, Y. Cao, J. Hyun Chang, K. Gambhir, et al. “Democratizing Self-Driving Labs through User-Developed Automation Infrastructure.” *ChemRxiv*, February 13, 2025. https://doi.org/10.26434/chemrxiv-2025-zhkrf.

14.2 Schlieren imaging is a workhorse in Dr Staymates' laboratory, enabling his team to visualise the movement of vapours with refractive indices different from that of air. This helps support best practices for canine training and trace sampling in the field. Seeing how vapours from homemade explosives and improvised explosive devices leak out of various objects helps identify the best approaches for sampling and detecting these threats. Using an anatomically correct artificial dog nose and schlieren imaging, they have shown how the dog is an active aerodynamic sampling system, utilising fluid dynamics to increase its ability to sample vapours and aerosols from large distances. As a form of biomimicry, the team now uses bio-inspired design principles from the dog and is applying them to current and next-generation sampling technology.[21] Additionally, a new background-oriented schlieren system was recently developed that enables large-scale visualisation of how the human thermal plume interacts with the environment and has an interesting and important impact on the nature of odour plume dynamics around the human body.

14.3 Dr Staymates noted that laser light-sheet imaging is another key tool used in this programme, enabling the visualisation of the spread of microscopic contamination during the manufacturing of homemade explosives and illicit drugs.[22,23] In his laboratory, they have coupled qualitative flow visualisation techniques with quantitative chemical analysis techniques to help identify the generation, evolution, transport, and ultimate fate of trace contamination during these activities. This technique is also used to study the spread of gunshot residue that emerges during a gunshot, and shows how the highly turbulent plume is transported in three dimensions. Laser light-sheet imaging is also used for exploring best practices for forensic laboratories during toxic material processing activities, in addition to visualising potential contamination hazards during common activities in laboratory settings.

14.4 The large number of examples and applications of flow visualisation tools presented by Dr Staymates clearly demonstrated their utility and sparked much discussion among the Board members. One of the key questions raised was the minimum particle size that can be detected, and whether changing the wavelength of the laser could affect the particle size detection limit. Dr Staymates responded that he has yet to perform experiments to elucidate the minimum particle size that can be detected, but it is of scientific interest. His research requires the detection of particles larger than 1 micrometre, which can be achieved with the laser. He suggested that while nano-sized particles may fall outside the detection limit, if they are present in sufficient quantities, their large surface area could scatter enough light for them to be detected. Questions were also raised regarding the selectivity of the technique, specifically whether it could identify organophosphate chemicals and distinguish between two different vapours in a cloud of toxic gas. Finally, the use of the laser to determine the optimal placement of sensors was also discussed.

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21 Staymates, M. E., W. A. MacCrehan, J. L. Staymates, R. R. Kunz, T. Mendum, T.-H. Ong, G. Geurtsen, G. J. Gillen, and B. A. Craven. "Biomimetic Sniffing Improves the Detection Performance of a 3D Printed Nose of a Dog and a Commercial Trace Vapor Detector." *Scientific Reports* 6, no. 1 (December 1, 2016). https://doi.org/10.1038/srep36876.

22 Sisco, E., M. E. Staymates, and L. M. Watt. "Net Weights: Visualizing and Quantifying Their Contribution to Drug Background Levels in Forensic Laboratories." *Forensic Chemistry* 20 (August 2020): 100259. https://doi.org/10.1016/j.forc.2020.100259.

23 Sisco, E., M. E. Staymates, and A. Burns. "An Easy to Implement Approach for Laboratories to Visualize Particle Spread during the Handling and Analysis of Drug Evidence." *Forensic Chemistry* 18 (May 2020): 100232. https://doi.org/10.1016/j.forc.2020.100232.

15. AGENDA ITEM FIFTEEN – Rapid chemical sensing for olfactory navigation

15.1 Dr Michael Schmuker from the University of Hertfordshire, the United Kingdom of Great Britain and Northern Ireland, presented his research and focused on how gas plume dispersal, turbulence, and fluctuating gas concentrations impact source localisation and navigation. He highlighted how biologically inspired chemical sensing can improve odour-based navigation, environmental monitoring, and security applications.

15.2 Dr Schmuker described how olfaction—the sense of smell—enables animals and insects to locate an odour-emitting source. What animals like dogs and moths achieve rapidly and with ease still poses a huge challenge for machines. Nevertheless, chemical sensing is attractive for a plethora of applications, such as locating gas sources in environmental monitoring, disaster management, and industrial security.

15.3 A unique challenge in chemical sensing is posed by how odours travel from their source to the site of detection. Unlike light, which guides vision and follows a straight line, odours are transported by the chaotic process of turbulent dispersion. A stream of odour that is continuously released into a turbulent air current is quickly broken up into filaments, which are mixed with clean air in swirling eddies. As a result, measured odour intensity at a fixed location has only weak correlation to source distance.

15.4 Using a wind tunnel, Dr Schmuker and his team have analysed these temporal fluctuations in data recorded with an electronic gas sensor.[24] They determined that the number of odour encounters, quantified by events of rapidly rising odour concentration, is a strong indicator of source distance in an upwind direction. In addition, the irregularity of these events rises as the edge of the odour plume is approached. This work showed that the temporal fluctuation of odour intensity bears critical information on the location of its source.

15.5 For machines to exploit this information to locate odour sources, they need to be equipped with sensors that can resolve fluctuations in odour concentration with high temporal precision and resolution. While most commercial gas sensors are incapable of resolving concentration fluctuations below tens of seconds, there are several known methods to accelerate their response. Combining several of these approaches, Dr Schmuker's team have developed a novel rapid electronic nose (e-nose), leveraging metal-oxide gas sensors with fast heater cycling to accelerate adsorption-desorption processes and enhance detection speed. Traditional gas sensing technologies like gas chromatography-mass spectrometry (GC-MS) are precise but slow and bulky, while photoionisation detectors are fast but lack specificity. The e-nose overcomes these limitations by rapidly cycling sensor temperatures, allowing for near-real-time gas recognition.

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[24] Schmuker, M., V. Bahr, and R. Huerta. "Exploiting Plume Structure to Decode Gas Source Distance Using Metal-Oxide Gas Sensors." *Sensors and Actuators B: Chemical* 235 (November 2016): 636–46. https://doi.org/10.1016/j.snb.2016.05.098.

15.6 Through signal processing and machine learning, the e-nose successfully classified different odour pulses, even for exposure times as short as 20 to 50 milliseconds—a detection speed comparable to olfaction in mice.[25] Field tests demonstrated that the system could reliably recognise “olfactory scenes”, distinguishing between various indoor environments based on ambient chemical signatures.

15.7 Finally, Dr Schmuker presented experiments on robot navigation using odour cues, in which an omnidirectional robot equipped with the e-nose followed a pulsed odour source. The robot used an event-driven algorithm, mimicking insect behaviour by adjusting its movements based on detected odour concentration. The trajectory resembled the “casting and surging” search patterns observed in insects, suggesting practical applications for autonomous olfactory navigation. Dr Schmuker noted that this research could lay the foundation for faster, more reliable gas-based robot navigation by enabling more accurate tracking of odour plumes and extracting temporal features from the environment—insights that slower standard sensors would miss.

15.8 Board members raised several questions about the experimental conditions, the applicability of the gas diffusion models to aerosols and fine particulates, and the machine learning algorithm, particularly regarding their relevance to real-world scenarios. For instance, the wind tunnel does not account for obstacles such as trees and buildings, while the machine learning model is limited to indoor conditions and does not consider variations in temperature, pressure, humidity, and other outdoor factors. Additionally, the SAB inquired about the types and number of metal-oxide sensors used in the e-nose. They also questioned whether the robot’s sensitivity changed as battery life decreased and whether, similar to animals, the e-nose could learn to identify new odours based on previously learned patterns.

16. AGENDA ITEM SIXTEEN – Drone-based localisation of hazardous chemicals by passive smart dust

16.1 Dr Michael Weller from the Bundesanstalt für Materialforschung und -prüfung (BAM), Germany, presented recent research on detection technologies conducted by his team. He opened with a brief overview of BAM, explaining that, as Germany’s Federal Institute for Materials Research and Testing, it is analogous to the NIST in the United States of America and produces more than 400 quality assurance standards, which it provides for sale. Dr Weller also outlined the key fields of activity and priority topics at BAM that are relevant to his work, including security and sensor technology.

16.2 Dr Weller then provided additional background on his work on detecting hazardous chemicals using drone and smart dust technologies. He explained that one of the long-standing challenges with drone-based detection is “downwash”, a phenomenon caused by rotor movement. This effect can dilute and disperse analytes, reducing local resolution and making effective sampling and detection more difficult. Dr Weller also noted that his team’s work was inspired by the concept of smart dust,[26] which originated over 20 years ago as part of an initiative of the Defense Advanced Research Projects

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25 Dennler, N., D. Drix, T. P. Warner, S. Rastogi, C. Della Casa, T. Ackels, A. T. Schaefer, A. van Schaik, and M. Schmuker. “High-Speed Odor Sensing Using Miniaturized Electronic Nose.” *Science Advances* 10, no. 45 (November 8, 2024). https://doi.org/10.1126/sciadv.adp1764.

26 Warneke, B., M. Last, B. Liebowitz, and K.S.J. Pister. “Smart Dust: Communicating with a Cubic-Millimeter Computer.” *Computer* 34, no. 1 (2001): 44–51. https://doi.org/10.1109/2.895117.

Agency (DARPA). While the use of smart dust as sensor networks showed initial promise, several disadvantages—including high cost, energy limitations, and environmental impact—precluded further work at the time.

16.3 Rapid detection and localisation of hazardous chemicals is crucial for environmental monitoring, occupational safety, and emergency response. Dr Weller and his team have developed a novel approach that combines drone technology with passive smart dust—biodegradable, paper-based chemical detectors—to remotely identify and map hazardous substances.[27] In contrast to earlier smart dust concepts based on electronic microsensors, this method uses cellulose-based, confetti-like sensors impregnated with colorimetric or fluorescent indicators. These sensors change colour in response to chemical exposure, enabling simple optical detection from a distance.

16.4 A drone equipped with a conventional digital camera takes pictures of the deployed sensors, which are then analysed by automated image processing. The system converts images from the red-green-blue (RGB) colour model into hue-saturation-value (HSV) space and applies threshold filters and clustering algorithms to increase the accuracy of identifying hazardous zones. Field tests using thymol blue as a pH-sensitive indicator have successfully demonstrated the ability of the system to detect and locate acid spills in an outdoor environment. The results confirmed that low-cost, commercial off-the-shelf drones can effectively monitor affected areas by providing real-time data for responders, while minimising human exposure to hazardous chemicals.

16.5 This approach offers a fast, cost-effective, and environmentally friendly alternative to conventional hazard detection technologies. Dr Weller noted that other important advantages are the close proximity of the sensors to the contamination, the avoidance of downwash problems by the drone propellers, and the generation of a dense mesh of data points. Since no complex electronic sensors are required, and simple, biodegradable materials are used, the system is well suited for large-scale deployment in industrial accidents, environmental pollution, and chemical disaster scenarios. Future research will investigate additional chemical indicators to expand detection capabilities, optimise sensor deployment, and refine data processing for greater accuracy. The passive smart dust system represents a new concept in remote chemical hazard monitoring and may have broad implications for accident response, environmental crime, facility security, and chemical attacks.

16.6 The SAB agreed that the novel approach presented by Dr Weller shows promise for detecting chemical warfare agents, in addition to its existing applications for hazardous chemicals. They noted its many advantages, including simplicity and low cost. The described applications principally focused on pH indication through colour changes. The SAB enquired whether oxidising agents could also be detected via colorimetric methods and how fluorescence could be effectively detected, given that an ultraviolet lamp is typically required. Discussions also addressed the use of detection paper specifically for chemical warfare agents, the detection of multiple chemicals by simply mixing different paper-based sensors, the feasibility of achieving an even distribution of the confetti-like smart dust, its detectability on contaminated soil, the potential for combining this approach with drone-based sampling, and the environmental impact and potential recovery of the smart dust.

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27 Nerger, T., P. P. Neumann, and M. G. Weller. “Drone-Based Localization of Hazardous Chemicals by Passive Smart Dust.” *Sensors* 24, no. 19 (September 25, 2024): 6195. https://doi.org/10.3390/s24196195.

17. AGENDA ITEM SEVENTEEN – Fluorescent and colorimetric detection of chemical warfare agents: A journey towards accurate detection and differentiation

17.1 Dr Vinod Kumar from the Defence Research and Development Establishment, India, began by briefly outlining different categories of chemical warfare agents and noting the current chemical- and instrument-based detection methods. He highlighted that while a number of techniques are available, there are pros and cons associated with each one. Given the potential threat of use of chemical warfare agents, Dr Kumar stressed the importance of having a robust and reliable chemical sensor and detection system, comprising readily deployable chemical probes that can operate with high specificity and sensitivity.

17.2 Over the last decade, his group has been engaged in designing and developing novel field-deployable sensing techniques by exploring approaches based on supramolecular tools, which can result in excellent specificity, sensitivity, high speed, portability, and low cost. Dr Kumar described the three primary modes of chemical sensing and noted that the chemodosimeter approach—based on covalent bond breaking or formation—has been most successful and has therefore become central to his research efforts.

17.3 During his presentation, Dr Kumar described his group's journey and success stories in the development of chemical warfare detection protocols, detailing the range of unique chemical probes and methods explored to achieve the specific detection of individual agents under real environmental conditions. Their research followed a stepwise approach in developing detection systems for chemical warfare agents. His team first focused on nerve agents, starting with tabun[28] and gradually expanding detection capabilities to include VX and then sarin.[29] Rather than redesigning the chemodosimeter itself, they focused on fine-tuning reaction conditions and eliminating interferents, ensuring high selectivity and reliability in real-world environments. Separately, they developed a distinct detection system for sulfur mustard, addressing the unique challenges posed by blister agents.[30,31,32] While both systems have proven effective within their respective categories, the ultimate goal of Dr Kumar's research is to create a single unified platform capable of detecting both nerve agents and vesicants—a challenge that remains an ongoing focus for his team.

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28 Kumar, V., and M. Parshad Kaushik. "Rapid and Highly Selective Chromogenic Detection of Nerve Agents with a Cleft-Shaped Host." *The Analyst* 136, no. 24 (2011): 5151. https://doi.org/10.1039/c1an15726d.

29 Kumar, V., and H. Rana. "Chromogenic and Fluorogenic Detection and Discrimination of Nerve Agents Tabun and VX." *Chemical Communications* 51, no. 92 (2015): 16490–93. https://doi.org/10.1039/c5cc06580a.

30 Kumar, V., and E. V. Anslyn. "A Selective Turn-on Fluorescent Sensor for Sulfur Mustard Simulants." *Journal of the American Chemical Society* 135, no. 16 (April 15, 2013): 6338–44. https://doi.org/10.1021/ja401845e.

31 Kumar, V., H. Rana, G. Raviraju, and A. K. Gupta. "Chemodosimeter for Selective and Sensitive Chromogenic and Fluorogenic Detection of Mustard Gas for Real Time Analysis." *Analytical Chemistry* 90, no. 2 (January 4, 2018): 1417–22. https://doi.org/10.1021/acs.analchem.7b04882.

32 Yadav, L. K., G. Raviraju, T. Roy, and V. Kumar. "A Highly Specific Colorimetric Detection of Sulfur Mustard and Nitrogen Mustard at Room Temperature with Iodine–Starch System." *Microchemical Journal* 211 (April 2025): 113169. https://doi.org/10.1016/j.microc.2025.113169.

17.4 After the presentation, Board members inquired whether Dr Kumar had applied his supramolecular detection approach to Schedule 1 carbamate compounds and whether their long alkyl chains and ionic nature might pose challenges. He confirmed that he had not yet investigated these compounds, but acknowledged that their distinct structures and lower reactivity could present difficulties. Following a question on organophosphate pesticides, Dr Kumar stated that his group had applied its chemical sensing approach to between 12 and 14 pesticides, with only malathion producing a positive response. The SAB members also posed questions on the varying solubilities of chemical warfare agents in water, the difference between chemodosimeter and encapsulation approaches, and the potential for false positives caused by contaminants in one of the metal-ligand complexes.

18. AGENDA ITEM EIGHTEEN – Miniaturised printed electrochemical biosensors for smart detection of chemical and biological warfare agents

18.1 Prof. Fabiana Arduini, from the University of Rome Tor Vergata, Italy, presented the use of miniaturised printed electrochemical biosensors for the smart detection of chemical and biological warfare agents. These devices combine advanced materials, such as carbon black, graphene-based structures, and nanoparticles, with biorecognition elements, including enzymes, antibodies, aptamers, and nucleic acids, to enable portable, sensitive, and cost-effective detection. Prof. Arduini highlighted that, by integrating these components with screen-printed electrode technologies, this approach allows for rapid on-site identification of hazardous agents, offering an accessible and field-deployable alternative to traditional analytical methods.

18.2 Electrochemical biosensors are particularly well-suited for the detection of chemical warfare agents. Prof. Arduini and her team have explored the use of cholinesterase-based biosensors to detect nerve agents by measuring the inhibition of enzymatic activity. They have developed a printed electrochemical biosensor integrated with a portable device which can detect sarin in the gas phase.[33,34] The system could clearly distinguish between different concentrations of the agent and was also able to detect concentrations as low as 0.1 mg/m^3, demonstrating both high sensitivity and suitability for field applications.

18.3 During her presentation, Prof. Arduini also introduced the use of paper-based printed electrochemical biosensors, which combine miniaturisation, low cost, sustainability, and operational simplicity. Working with her team, she has developed printed paper-based electrochemical biosensors for the detection of chemical warfare agents, including a fully integrated paper-based platform for the detection of nerve agents, using paraoxon as simulant.[35] These devices are designed using layers of wax-printed paper, paper-based screen-printed electrodes modified with carbon black and Prussian

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33 Arduini, F., A. Amine, D. Moscone, F. Ricci, and G. Palleschi. “Fast, Sensitive and Cost-Effective Detection of Nerve Agents in the Gas Phase Using a Portable Instrument and an Electrochemical Biosensor.” *Analytical and Bioanalytical Chemistry* 388, no. 5–6 (May 17, 2007): 1049–57. https://doi.org/10.1007/s00216-007-1330-z.

34 Arduini, F., D. Neagu, S. Dall’Oglio, D. Moscone, and G. Palleschi. “Towards a Portable Prototype Based on Electrochemical Cholinesterase Biosensor to Be Assembled to Soldier Overall for Nerve Agent Detection.” *Electroanalysis* 24, no. 3 (January 11, 2012): 581–90. https://doi.org/10.1002/elan.201100540.

35 Cinti, S., C. Minotti, D. Moscone, G. Palleschi, and F. Arduini. “Fully Integrated Ready-to-Use Paper-Based Electrochemical Biosensor to Detect Nerve Agents.” *Biosensors and Bioelectronics* 93 (July 2017): 46–51. https://doi.org/10.1016/j.bios.2016.10.091.

blue nanoparticles, and nitrocellulose strips. The biosensor operates by detecting the inhibition of butyrylcholinesterase activity. It has been validated with real samples such as river and wastewater, showing high recovery rates and excellent reproducibility.

18.4 In addition to this system for the detection of nerve agents, Prof. Arduini also highlighted work to develop origami paper-based biosensors for mustard agents. One study, in collaboration with the Bundeswehr Institute of Pharmacology and Toxicology in Germany, involved the use of Prussian blue nanoparticles and choline oxidase for the detection of sulfur mustard simulant.[36] The wearable origami-like biosensor was able to detect even low concentrations of mustard agents in the aerosol phase, aligning with operational exposure limits.

18.5 Finally, Prof. Arduini shared examples of sensors developed by her group to detect a variety of biological agents, including SARS-CoV-2[37] and botulinum biotoxins.[38]

18.6 The SAB members acknowledged the importance of this work and questioned why, despite the availability of numerous laboratory prototypes, point-of-care devices are still lacking in the field. In response to a question about immobilised antibodies and orientation issues, Prof. Arduini explained that her group uses magnetic beads to address this challenge. She also highlighted her preference for carbon black over graphene, citing its superior electrochemical performance, lower cost, which supports future scalability, and the absence of the additional treatment step required for graphene.[39]

19. AGENDA ITEM NINETEEN – Pesticides: Analyses and treatment

19.1 Dr Moussa Mokhtari from the Scientific and Technical Research Centre in Physico-chemical Analysis, Algeria, delivered a comprehensive presentation on the analysis and treatment of pesticides. He began by providing a historical overview of pesticide development, tracing their origins from early uses of natural substances in the Arab world to the emergence of synthetic chemical pesticides in the 20th century. Dr Mokhtari explained that pesticides may be classified in various ways, including according to their biological targets, mode of application, and chemical composition. He identified four key chemical groups: carbamates, synthetic pyrethroids, organochlorines, and organophosphates, and highlighted notable examples within each category.

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36 Colozza, N., K. Kehe, G. Dionisi, T. Popp, A. Tsoutsoulopoulos, D. Steinritz, D. Moscone, and F. Arduini. “A Wearable Origami-like Paper-Based Electrochemical Biosensor for Sulfur Mustard Detection.” *Biosensors and Bioelectronics* 129 (March 2019): 15–23. https://doi.org/10.1016/j.bios.2019.01.002.

37 Fabiani, L., M. Saroglia, G. Galatà, R. De Santis, S. Fillo, V. Luca, G. Faggioni, et al. “Magnetic Beads Combined with Carbon Black-Based Screen-Printed Electrodes for COVID-19: A Reliable and Miniaturized Electrochemical Immunosensor for SARS-COV-2 Detection in Saliva.” *Biosensors and Bioelectronics* 171 (January 2021): 112686. https://doi.org/10.1016/j.bios.2020.112686.

38 Caratelli, V., S. Fillo, N. D’Amore, O. Rossetto, M. Pirazzini, M. Moccia, C. Avitabile, D. Moscone, F. Lista, and F. Arduini. “Paper-Based Electrochemical Peptide Sensor for on-Site Detection of Botulinum Neurotoxin Serotype A and C.” *Biosensors and Bioelectronics* 183 (July 2021): 113210. https://doi.org/10.1016/j.bios.2021.113210.

39 Arduini, F., S. Cinti, V. Mazzaracchio, V. Scognamiglio, A. Amine, and D. Moscone. “Carbon Black as an Outstanding and Affordable Nanomaterial for Electrochemical (Bio)Sensor Design.” *Biosensors and Bioelectronics* 156 (May 2020): 112033. https://doi.org/10.1016/j.bios.2020.112033.

19.2 Dr Mokhtari presented a brief overview of the global pesticide market, noting its growth worldwide and highlighting that the highest rates of growth have been seen in South America and Africa. He remarked that there has been a continuous upward trend in pesticide consumption over the past 30 years.

19.3 After introducing the various mechanisms of action of herbicides, fungicides, and insecticides, Dr Mokhtari focused on the health effects associated with pesticide exposure, which may be allergic, acute, or delayed in nature. Delayed effects include developmental and reproductive complications, as well as systemic disorders affecting the liver, kidneys, and nervous system. Dr Mokhtari also highlighted best practices in pesticide safety, including storage, transportation, application, and waste disposal, emphasising the importance of trained personnel and environmental precautions.

19.4 Dr Mokhtari then shifted focus to the analytical methods used in pesticide detection, first highlighting that careful attention to sampling and sample preparation is essential for obtaining reliable results. Analytical methods range from traditional chromatography (LC-MS, GC-MS) to advanced techniques such as hyperspectral imaging, electrochemical sensors, and surface-enhanced Raman scattering. Dr Mokhtari noted that the utility of receptor-based assays and embedded technology platforms was also explored for efficient field-level monitoring.

19.5 Finally, the presentation addressed pesticide remediation techniques in soil and water, including bioremediation, chemical oxidation, soil stabilisation, and photocatalytic degradation using combined materials like titanium dioxide and polyaniline.[40] Dr Mokhtari closed by emphasising that while pesticides are human-made substances, their environmental and health impact is determined by the manner in which they are utilised.

19.6 The ensuing discussion with the Board covered multiple themes related to the toxicity, use, and detection of pesticides. Specifically relating to malathion, Dr Mokhtari clarified that malaoxon is its main in vivo metabolism product. Although malaoxon is significantly more toxic, malathion is used in agriculture because of its production feasibility, lower direct toxicity to humans, and better environmental stability. Challenges in the degradation and detection of diverse pesticide classes were discussed. It was noted that no single chemical method is universally effective due to the varied chemical structures of pesticides, necessitating combined treatment approaches—biological, chemical, and physical—for effective degradation. Additional topics included factors influencing the continued use of toxic pesticides, the benefits of improving farmer education, global paralytic shellfish poison biotoxin analysis methods, and the potential of AI to design less toxic pesticides. The SAB agreed on the inevitability and necessity of integrating AI into future pesticide development and toxicity prediction.

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40 Benhalima, T., M. Mokhtari, and H. Ferfera-Harrar. "Synergistic Adsorption/Photodegradation Effect for Effective Removal of Crystal Violet Dye and Acetamiprid Pesticide Using FE^{3+} Cross-Linked Ternary Carboxymethyl Cellulose/Polyaniline/Tio_2 Photocomposites." *Journal of Water Process Engineering* 57 (January 2024): 104670. https://doi.org/10.1016/j.jwpe.2023.104670.

20. AGENDA ITEM TWENTY – SAB discussion on its approach to the Sixth Review Conference

20.1 The Secretary to the SAB recalled the approach of the Board in its preparations for the report of the SAB to the Fifth Review Conference, describing the breadth of activities undertaken during the five-year timeline. He outlined the work of the Board by topic, noting that these topics were divided into smaller focus areas which were each addressed by a subgroup. Working backwards from an assumed date for the Sixth Review Conference, the Secretary recommended that the report of the SAB should be prepared by early autumn 2027.

20.2 As a result of the initial discussion at the Thirty-Eighth Session of the SAB on its report to the Sixth Review Conference, combined with topics from its previous report on developments in science and technology, a detailed mind map was produced. This served as the foundation for the Board’s discussions during the session and generated significant engagement. For several topics, the Board debated whether sufficient developments had occurred since the last report to warrant inclusion. The members also proposed reassigning certain topics and subtopics between categories, while additional relevant subtopics were included in draft plan. All discussions and proposals were captured by the Chairperson and Secretary and will be reflected in an updated mind map. The Secretary encouraged SAB members to continue considering this future report and to share further ideas by correspondence during the intersessional period.

21. AGENDA ITEM TWENTY-ONE – SAB Chairperson and Vice-Chairperson election

The Board, with the assistance of the SAB Secretary, held a private meeting to elect its Chairperson and Vice-Chairperson for 2026. No interpretation was provided, and only Board members physically present were in attendance. Dr Matteo Guidotti was elected as Chairperson, and Prof. Elisa Souza Orth was re-elected as Vice-Chairperson, by consensus, to serve in 2026.

22. AGENDA ITEM TWENTY-TWO – SAB discussion on conferences, meetings, and publications

22.1 The Board discussed upcoming conferences of note. Dr Crister Åstot provided an overview of the 15th CBRNe Protection Symposium to be held in Malmö, Sweden, from 30 September to 2 October 2025, noting the different thematic sessions and highlighting the keynote speakers. The Board also discussed other conferences of relevance, including the IUPAC[41] World Chemistry Congress to be held in Kuala Lumpur, Malaysia in July 2025, the ACS Fall 2025 meeting in Washington, DC, United States of America, in August 2025, and the 7th International Conference on CBRNe Research & Innovation, to be held in Arcachon, France, in May 2026.

22.2 Prof. Elisa Souza Orth, currently the President of the organising committee for meetings of the Brazilian Chemical Society, highlighted that at the upcoming 48th Annual Meeting from 8 to 11 June, there will be a session on chemical safety and security. She noted there may be an opportunity to hold a workshop during next year’s meeting on a topic of relevance to the SAB.

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[41] International Union of Pure and Applied Chemistry.

22.3 The Board discussed publication of the report of the SAB on developments in science and technology to the Fifth Review Conference with a view to submitting it to *Pure and Applied Chemistry*, an IUPAC journal. The article would summarise the report of the SAB to the Fifth Review Conference and provide an update on topics of current interest to the Board. The SAB Chairperson and Vice-Chairperson encouraged any Board members interested in contributing to contact them.

23. AGENDA ITEM TWENTY-THREE – Any other business

No matters were raised under this agenda item.

24. AGENDA ITEM TWENTY-FOUR – Closing remarks

24.1 The SAB Chairperson thanked the staff of the Secretariat and the interpretation team for their support at this successful session, and congratulated the newly elected Chairperson and Vice-Chairperson. She recalled that this was her last SAB meeting, as she would be leaving the Board at the end of 2025. Several departing Board members shared some final remarks, highlighting the professional and personal benefits of serving on the Board. Finally, Prof. Martinez thanked all the Board members for their participation and contribution to the Thirty-Ninth Session of the SAB.

24.2 The SAB is grateful to all States Parties, organisations, and institutions that have provided financial assistance to the work of the Board. In particular, it extends its thanks to both Mexico and the Philippines for their recent contributions to the SAB Trust Fund as well as the European Union and the United States of America, whose funding has made the work of the current, ongoing TWGs possible.

25. AGENDA ITEM TWENTY-FIVE – Adoption of the report

The Board adopted the report of its Thirty-Ninth Session by consensus.

26. AGENDA ITEM TWENTY-SIX – Closure of the session

The Chairperson closed the Thirty-Ninth Session of the SAB at 16:50 CET on 4 April 2025.

Annexes:

Annex 1: List of Participants in the Thirty-Ninth Session of the Scientific Advisory Board

Annex 2: Terms of Reference of the Temporary Working Group on Artificial Intelligence

Annex 1

LIST OF PARTICIPANTS IN THE THIRTY-NINTH SESSION OF THE SCIENTIFIC ADVISORY BOARD

	Participant	**Institution**
	Members of the Scientific Advisory Board	
1.	Dr Tareq AlAhmadi	King Fahd Security College, Saudi Arabia
2.	Dr Crister Åstot	Swedish Defence Research Agency (FOI), Sweden
3.	Prof. Allisson Astuya Villalón	University of Concepción, Chile
4.	Dr Karim Ben Ali	Tunisian Military Research Center, Tunisia
5.	Capt. Elma Biscotti	Scientific and Technical Research Institute for Defense (retired), Argentina
6.	Dr Anne Bossée	DGA CBRN Défense, France
7.	Dr Cindi Corbett	Public Health Agency of Canada's National Microbiology Laboratory (NML), Canada
8.	Mr Raza Ellahi	Defence Science & Technology Organization (DESTO), Pakistan
9.	Dr Norman Govan	Defence Science and Technology Laboratory, United Kingdom of Great Britain and Northern Ireland
10.	Dr Matteo Guidotti	Institute of Chemical Sciences and Technologies (SCITEC) of the Italian National Research Council, Italy
11.	Prof. Keunhong Jeong	Korea Military Academy, Republic of Korea
12.	Dr Robert Kristovich	Defense Threat Reduction Agency, United States of America
13.	Prof. Imee Su Martinez (Chairperson)	University of the Philippines-Diliman, Philippines
14.	Dr Catharina Müller-Buschbaum	Accenture, Germany
15.	Prof. Elisa Souza Orth (Vice-Chairperson)	Federal University of Paraná, Brazil
16.	Dr Meehir Palit	Defence Research and Development Organisation, India
17.	Prof. Ines Primožič	University of Zagreb, Croatia
18.	Dr Moussa Sehailia	Scientific and Technical Research Centre in Physico-chemical Analysis, Algeria
19.	Prof. Sermet Sezigen	University of Health Sciences, Department of Medical CBRN Defense, Turkïye
20.	Dr Raja Subramaniam	National Authority for Chemical Weapons Convention, Malaysia
21.	Prof. Fengxia Sun	Hebei University of Science and Technology, China
22.	Prof. Vessela Tsakova-Stancheva	Institute of Physical Chemistry at the Bulgarian Academy of Sciences, Bulgaria
23.	Dr Normandla Magnificent Vela	Protechnik Laboratories, South Africa

	Participant	Institution
Secretary to the Scientific Advisory Board		
24.	Dr Peter Hotchkiss	Organisation for the Prohibition of Chemical Weapons, Netherlands
Invited Speakers		
25.	Prof. Fabiana Arduini	University of Rome Tor Vergata, Italy
26.	Mr Sébastien Braha	Organisation for the Prohibition of Chemical Weapons, Netherlands
27.	Dr Mirjam de Bruin-Hoegée	Netherlands Organisation for Applied Scientific Research (TNO), Netherlands
28.	Dr Ruud Busker	Netherlands Organisation for Applied Scientific Research (TNO), Netherlands
29.	Dr Vinod Kumar	Defence Research and Development Organisation, India
30.	Dr Pernilla Lindén	Swedish Defence Research Agency (FOI), Sweden
31.	Mr Adriaan Marais	Organisation for the Prohibition of Chemical Weapons, Netherlands
32.	Dr Moussa Mokhtari	Scientific and Technical Research Centre in Physico-chemical Analysis, Algeria
33.	Prof. Nadya Peek	University of Washington, United States of America
34.	Dr Michael Schmuker	University of Hertfordshire, United Kingdom of Great Britain and Northern Ireland
35.	Dr Matthew Staymates	National Institute of Standards and Technology (NIST), United States of America
36.	Dr Michael Weller	Bundesanstalt für Materialforschung und -prüfung (BAM), Germany
Official Observers		
37.	Dr Ladislava Navrátilová	Advisory Board on Education and Outreach
38.	Prof. Supawan Tantayanon	Advisory Board on Education and Outreach

Annex 2

TERMS OF REFERENCE OF THE TEMPORARY WORKING GROUP ON ARTIFICIAL INTELLIGENCE

1. Artificial intelligence (AI) is emerging as a powerful enabling technology that is increasingly being integrated into many other disciplines and technologies, including biotechnology, robotics, and drones. The resultant synergistic effect can significantly enhance capabilities beyond what each technology can achieve in isolation. AI is accelerating progress in chemistry and related fields, in addition to making associated processes cheaper, faster, and more effective.

2. AI, particularly in relation to risks, governance, and regulation, is continuing to capture significant attention, both nationally and regionally, in addition to coming to the fore within a range of international organisations, including the United Nations and the OPCW. In its recent comprehensive scientific report submitted to the Fifth Review Conference (RC-5/DG.1, dated 22 February 2023), the Scientific Advisory Board (SAB) identified a number of potential risks posed by the misuse of AI, including its use and integration in other technologies, as well as opportunities that this technology may afford the OPCW in its implementation of the Chemical Weapons Convention (the Convention).

3. Given the novelty of AI, its unprecedented pace of development, and its rapid inclusion in many fields, it behoves the OPCW to identify and understand the potential impacts AI might have on its mission to achieve a world free of chemical weapons, to prevent the re-emergence of chemical weapons, and to promote the peaceful uses of chemistry. Consequently, in accordance with paragraph 9 of the terms of reference of the SAB (Annex to C-II/DEC.10/Rev.1, dated 2 December 2004), the Director-General has decided to establish a Temporary Working Group (TWG) on Artificial Intelligence and has appointed Dr Catharina Müller-Buschbaum as the Chairperson of the Group.

4. Through a review of current AI capabilities and technology adoption, the objective of the TWG is to understand the impact of the technology on the object and purpose of the Convention and identify the risks to and opportunities for its implementation. The findings will be considered by the SAB and recommendations will be provided to the Director-General.

5. The TWG will consist of individuals who have expertise in AI, especially in the context of the chemical sciences. Group members may have expertise in a range of subfields of AI, including machine learning, deep learning, natural language processing, robotics, and computer vision; the application of AI in research and/or industry relating to chemical sciences or data analytics; AI ethics and governance; or experience of implementation of the Convention. The TWG will comprise qualified members of the SAB as well as representatives from the chemical industry and relevant academic and scientific organisations. Guest speakers from all geographical regions will be invited to assist the TWG in its collection of data and information, and formulation of advice.

6. The TWG will provide a summary of the current state of the art, and expected near-term progress to be made, in the following areas:

   (a) synthesis and retrosynthesis prediction;

   (b) automated and remote synthesis and production of chemicals;

   (c) data curation, protection, and reliability;

   (d) property, spectral, and data prediction and generation;

   (e) data/sensor fusion for augmented detection and analysis; and

   (f) simulation and training.

7. While considering the six technical areas set out in question 6, the TWG should ensure that the following questions are also addressed:

   (a) What new capabilities are being enabled, that is, what can be done now that was not possible before? Consider both opportunities and risks.

   (b) What are the current limitations and challenges to further progress, and which obstacles are likely to remain difficult or impossible to overcome?

   (c) What external, non-technical factors exist that may accelerate or enable progress and/or technology adoption or slow it down?

8. The TWG is also requested to consider how advances in AI will impact the implementation of the Convention and the work of the OPCW by considering the following questions:

   (a) What red flags or anomalies could help in identifying the potential misuse of AI systems?

   (b) Which specific AI applications are sufficiently mature for the OPCW to utilise in augmenting its capabilities?

   (c) What changes will be seen in industry in the coming years as AI becomes increasingly integrated into chemical production processes?

   (d) How might AI impact verification efforts, either by increasing risks or by presenting opportunities?

   (e) What existing guardrails and governance frameworks in the AI domain could be used, or further developed, to prevent the misuse of AI within the context of the Convention?

   (f) How can the OPCW promote the responsible use of AI in relation to the Convention?

9. The TWG will also highlight and consider any other application areas of AI that may be relevant within the context of this work.

10. On the basis of this in-depth review and assessment, the TWG will provide a list of recommended short- and long-term actions to ensure that AI can be harnessed for good and that its associated risks can be mitigated or, as a minimum, closely monitored.

11. The Director-General might pose additional, related questions to the TWG, through the SAB.

12. The TWG will exist for a period of one year starting on 1 January 2025. Thereafter, its work will be reviewed by the SAB and the Director-General, and a decision will be made as to whether it should continue its work and, if so, whether these terms of reference should be revised.

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