POLICY FORUM

SCIENCE AND SECURITY

Countering the future chemical weapons threat

Shift focus from disarmament to preventing reemergence

By **Tuan H. Nguyen**

After decades of difficult negotiations, the Chemical Weapons Convention (CWC) was adopted in 1993 and entered into force on 29 April 1997, banning the development, production, stockpiling, transfer, and use of chemical weapons (CW). As the CWC celebrates the 25th anniversary of its entry into force, it can document considerable success, much of it attributed to the CWC implementing body—the Organisation for the Prohibition of Chemical Weapons (OPCW). Yet, facing a volatile international security environment and an everchanging chemical industry, the OPCW must transform to meet its mission and remain an exemplar for multilateralism. As the next CWC review conference approaches in 2023, a next-generation OPCW 2.0 can be effective and credible only if it reinforces international norms against CW, anticipates future challenges posed by advancements in science and technology (S&T), incorporates more qualitative elements into the verification and compliance system, and keeps pace with technological change.

The CWC is the first multilateral disarmament agreement to provide for the comprehensive ban, including elimination, of an entire category of weapons of mass destruction (WMD). The treaty has almost universal membership. The OPCW, which was awarded the Nobel Peace Prize in 2013, has conducted more than 4200 total industry inspections and overseen the destruction of 99% (71,614 metric tons) of the world's declared CW stockpiles (*1*).

TOWARD THE OPCW 2.0

Since entry into force, the OPCW's primary focus has been on the elimination of existing CW stockpiles and production capacities and the prevention of their acquisition in the future. The OPCW routine verification activities center around the continuous monitoring of CW stockpile destruction and the highly intrusive on-site inspections of industry facilities to ensure that they are not diverted for CW-related activities. By September 2023, all remaining declared CW stockpiles and equipment are to be eliminated (*2*). The OPCW will transition from an organization focused on chemical disarmament to one dominated by nonproliferation and threat-reduction activities. Given the recent use of CW in a civil war and for assassinations, the OPCW will increasingly focus on states and nonstate actors that are developing or using CW.

Thus, the OPCW 2.0 will see time and resources that are now devoted to the elimination of declared stocks repurposed for nonroutine verification activities. These include investigations of alleged CW use, challenge inspections, and more routine industry inspections, especially of other chemical production facilities (OCPFs), which manufacture large quantities of discrete organic chemicals that contain phosphorus, sulfur, or fluorine—the common constituents of blister and nerve agents—that are not on the CWC schedule of banned and controlled chemicals. To remain effective and credible, the challenge for the OPCW is that it must transform itself as a technical organization in a highly polarized political environment.

REINFORCING NORMS

For its survival and relevancy in the future, negotiators recognized the need for the CWC to be a dynamic document that empowers the OPCW to evolve, adapt, and adjust for the possibility of improvement based on a changing threat environment. The OPCW 2.0 must reinforce international norms against CW by exercising existing verification mechanisms and strengthening them by enhancing its technical capacity and developing new technical tools. Many questions arise. How do the States Parties and OPCW reduce the benefit and utility of CW programs to violators? Should the States Parties and OPCW seek to invoke the challenge inspection mechanism, which is intended as a verification safety net to capture and deter clandestine and undeclared CW activities located in another member state?

Case studies can shape answers to such questions. Knowledge gained from the United Nations (UN) Special Commission's experience in dealing with CW stocks in Iraq after the Iran-Iraq War and Desert Storm in the 1980s and early 1990s, respectively, informed the negotiation of the CWC and the creation of the OPCW. This experience was critical to developing the intrusive industry verification regime, which is the hallmark of the CWC and the reason why it can still be effective in the future. More recently, the mission in Syria was a watershed moment for the OPCW. The coordination and cooperation by the international community in 2014 to remove, transport, and destroy Syria's CW stockpile was a powerful demonstration of effective multilateralism. However, the OPCW has much more work ahead. Allegations of CW use by Syria on multiple occasions from 2014 to 2018, as well as conclusions by the OPCW Fact-Finding Mission that CW were used on multiple occasions and by the OPCW-UN Joint Investigative Mechanism that attributed the sarin and chlorine attacks to the Syrian regime and the sulfur mustard attacks to the Islamic State of Iraq and the Levant (ISIL), are still denied by the perpetrators and their partners.

The standard-of-proof issue has been a long-standing problem for verification and compliance of arms control and disarmament agreements. It is a tall order to find, identify, and attribute activities that provide undisputable evidence of treaty violation. Without the ability to hold violators accountable, the CWC and OPCW will decrease in effectiveness in a postdisarmament future after all declared CW stockpiles have been destroyed. A step in the right direction was the 2018 decision by the States Parties granting the OPCW the mandate to investigate and attribute responsibility of alleged CW use in Syria, which included the establishment of an Investigation and Identification Team that functions under the direct authority of the OPCW director-general (*3*).

In addition to the mission in Syria, the OPCW has assisted in the investigation and confirmation of other recent incidents of alleged CW use. The OPCW provided technical assistance to the Malaysian government in 2017 when the VX nerve agent was used to assassinate Kim Jong-nam, the half-brother of Kim Jong-un, the leader of North Korea. Technical assistance from the OPCW was provided again in 2018 when a novichok agent was used in the assassination attempt on Sergei and Yulia Skripal in Salisbury, UK. Novichoks are a class of organophosphorus nerve agents developed by the former Soviet Union during the Cold War that were not listed on the

Center for Global Security Research and Global Security Directorate, Lawrence Livermore National Laboratory, Livermore, CA, USA. Email: thn@llnl.gov

CWC Annex on Chemicals at the time of the Salisbury attack. The OPCW confirmed the UK's finding that a novichok was used in the attack but did not provide attribution identifying the perpetrators of the assassination attempt. Nevertheless, the Salisbury case resulted in novichoks being added to Schedule 1 of the CWC Annex on Chemicals—the first time that the annex has been updated. Despite this, a novichok-type agent was used again in the 2020 assassination attempt on Alexei Navalny (*4*).

The lack of accountability for these incidents erodes and weakens the international norm against CW. The use of CW perpetuates doubts about the compliance of some States Parties and undermines the credibility and overall effectiveness of the CWC. The international community must be assured that all CW programs declared by member states are completely dismantled. From a disarmament perspective, this is the fundamental reason why accountability and credible attribution of CW use matter.

To address and investigate claims of noncompliance, negotiators included provisions in the CWC for member state–initiated mechanisms for the OPCW to investigate allegations of CW use and to conduct short-notice challenge inspections. To date, no member state of the CWC has requested a challenge inspection. There are many reasons for this, both technical and political. The standard-of-proof challenge raises doubts about the OPCW's technical capacity to find, identify, and attribute violations during a challenge inspection. The political risks of failure during a challenge inspection to find indisputable evidence to substantiate a cheating or violations charge could end up provoking a cycle of retaliatory challenge inspections. As such, challenge inspections should be thought of not only as a mechanism for cases where there is clear evidence of cheating and violations but also as an instrument to clarify ambiguities, resolve declarations inconsistencies and discrepancies, and address concerns about compliance to prevent violators from circumventing the CWC and undermining its effectiveness.

If the challenge inspection mechanism continues to remain unused, its deterrence value will decline. To aid in these investigative efforts, the OPCW 2.0 needs to enhance and further develop technical competencies in areas that include forensic science, evidence collection, data management, and crime-scene reconstruction. The 2019 report by an OPCW working group on investigative S&T provides activities that the OPCW should consider to enhance its technical and operational capabilities and capacity to provide technical assistance to member states and to effectively conduct nonroutine missions, such as fact finding and investigations for attribution (*5*).

ANTICIPATING S&T CHALLENGES

Advances in S&T lower the barriers for WMD proliferation by enabling alternative proliferation pathways that present challenges for verification and compliance regimes. The convergence of knowledge in the life and physical sciences and engineering disciplines is enabled and accelerated by information technology and expanded access to research findings, data, and advanced computing and algorithms. Advances in gene editing, biocomputations, and predictive biology tools coupled with systems biology will enable the design and tailoring of molecules that are well suited for an intended role or purpose. New additive manufacturing techniques, along with other just-in-time production technologies, can challenge verification and compliance protocols.

Yet many dual-use technologies required for CW production have been known for more than 70 years. The production of organophosphorus nerve agents is not fundamentally different from the production of commercial pesticides. Still, the synthesis of some organophosphorus nerve agents requires a few chemical reactions that are not common in the production of commercial pesticides, such as the fluorination and alkylation reactions that form the phosphoryl-fluoride functional group and phosphoryl-carbon bonds. The phosphoryl-carbon bond is critical to the physicochemical properties of organophosphorus nerve agents and guided the organization of the schedules of the CWC Annex on Chemicals.

Technicians with the Organisation for the Prohibition of Chemical Weapons conduct a mock investigation of dummy chemical weapons in Rijswijk, the Netherlands, in 2017.

To achieve phosphoryl-carbon bonds by the Michaelis-Arbuzov rearrangement reaction, one of the most important and fundamental reactions in organophosphorus chemistry, heat must be applied under traditional conditions. Large-scale production requires industrial-size heating mantles, heat exchangers, other specialized equipment, and safety containment measures. It had long been assumed that CW-capable facilities would have large footprints and distinctive signatures and be limited in number. But modern synthetic organic chemistry provides alternative methods and pathways. This same rearrangement reaction to form phosphoryl-carbon bonds can occur without heat and instead be catalyzed by visible light or common organic reagents at room temperature (*6*–*8*). Microwave energy can be used to efficiently carry out the transformation without the need for traditional heat sources (*9*). Most future WMD threats may thus have smaller footprints and less distinct signatures and be more closely associated with legitimate civilian-industrial activities rather than with highly centralized, large-scale weapons programs run by military entities (*10*).

The renaissance of photochemical and electrochemical methods for chemical synthesis is bringing forth a multitude of innovative chemical transformations. For decades, some of the prevailing challenges facing photochemistry and electrochemistry have been reproducibility, scale, and efficiency. Many of these issues may now be overcome by using continuous-flow platforms developed in collaboration with engineers and computer scientists. The scale-up potential of this approach is demonstrated by the synthetic output of a desired product at a rate exceeding 5 kg/day from simple precursors (*11*). The Michaelis-Arbuzov reaction can now be carried out in a continuous-flow and solvent-free method (*12*). Photocatalytic fluorinations have also been demonstrated in continuous flow as a mild alternative to traditional methods that are both highly toxic and corrosive, avoiding equipment lined with corrosion-resistant alloys and other specialized materials (*13*).

Such changes can make possible what was once thought challenging or impossible. Combined with changes in process chemistry enabled by automation, robotics, and algorithms to assist with synthetic design, reaction prediction, and starting material selection, modern synthetic organic chemistry will challenge the way verification inspections are done. Will inspectors be looking for the right signatures for CW production? Or should they be thinking about nontraditional precursors, nontraditional equipment and facilities, and maybe even nontraditional people? Mechanisms for verification and compliance of these new developments are not as clear, even though the CWC, more than any other multilateral arms control treaty, is highly detailed with its comprehensive verification system. The challenge for the OPCW 2.0 will be to ensure that inspectors are aware of these platform technologies, recognize their enabling capabilities, and understand the potential for CW production.

BECOMING MORE QUALITATIVE

Lessons can be learned from the Nuclear Non-Proliferation Treaty's 1997 Additional Protocol, which was a direct response to the discovery of secret nuclear weapons programs in Iraq and North Korea in the early 1990s (*14*). The Additional Protocol sought to strengthen and expand existing International Atomic Energy Agency (IAEA) safeguards for verification of nuclear technology. The purpose was to provide the international community with a measure of confidence that any diversion of material and technologies to a weapons program would be detected quickly.

To accomplish this, the underlying notion of the Additional Protocol was to restructure the IAEA safeguards regime from a quantitative system to one that was more qualitative. Instead of focusing only on accounting for declared quantities of nuclear material and monitoring declared activities, the Additional Protocol sought to focus more on providing a comprehensive picture of a State Party's activities. To achieve this, the amount and type of information provided to the IAEA expanded, the number and types of facilities subject to inspection increased, and environmental sampling during such inspections was made possible.

Today, the CWC verification regime is mostly quantitatively focused on complete accountability of all items declared for CW programs, whereas industry verification is basically to confirm the nonproduction of CW. OPCW inspectors do not have the authorization to detect chemicals other than those listed in the official OPCW analytical database, which is limited to scheduled chemicals. Although an Additional Protocol for the CWC is not appropriate because the nuclear and chemical threats are different, challenges posed by advances in S&T require the OPCW 2.0 to evolve the industry verification paradigm to become more qualitative to provide a more comprehensive picture of activities at declared facilities. For example, the site-selection methodology for inspection of OCPFs needs to be refined to target facilities that pose the greatest risk for diversion to CW production—perhaps inclusion of open-source information to enhance the verification process.

KEEPING PACE WITH TECHNOLOGY

In the past, countering the CW threat was primarily focused on keeping precursor materials and/or toxic chemicals out of the hands of proliferators by securing knowledge, specialized materials, and dedicated equipment. That strategy was believed to be effective because the infrastructure to support large-scale military CW campaigns was expected to have a large footprint, have many signatures, and require considerable scale-up time. While looking for large, questionable chemical facilities, efforts focused on regulation and control of construction or source-material transport. But today, substantial amounts of materials and knowledge can be gathered outside traditional supply chains, including through the internet. Proliferators can find recipes for chemical agents, as exemplified by the reemergence of illicit synthetic designer-drug networks that seem to stay one step ahead of regulators at a time when we face the prospect that substantial amounts of CW could be produced in low-profile facilities. New chemical production processes and technologies enable just-in-time production, the widespread adoption of which could facilitate treaty breakout scenarios in which a member state vacates disarmament commitments, reneges on treaty obligations, and rapidly rearms (*15*).

Fortunately, many of the same breakthrough technologies that will challenge the OPCW 2.0 will also afford the organization new enabling capabilities to accomplish its mission more effectively. Instead of relying solely on data from site inspections and declared information, more comprehensive assessments can be made with data analytic tools being adopted in the commercial sector, including data aggregation tools, space-based assets for "eyes on the ground" capabilities, and open-source information products. Advances in remote sensing and automated sampling systems could transform the way we think about and execute monitoring and verification activities. The OPCW 2.0 needs to keep pace with technological developments to improve the conduct of verification by adopting new methods and types of inspection equipment.

The mission of the OPCW 2.0 will not change: to implement the provisions of the CWC to advance the vision of a world free of threats from CW. The issue is not about what to do but how to do it. The greatest challenge for the OPCW 2.0 is not in the legal framework of the CWC or the tools needed to adapt, but rather the political will to use them. After 25 years, the CWC and the OPCW are at a crossroads. The path that the OPCW 2.0 takes will determine whether the CWC continues to be celebrated as a model for multilaterally negotiated arms control and disarmament and a central pillar to our strategy to counter WMD threats or risks becoming less effective in the future international security environment. ■

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ACKNOWLEDGMENTS

This article is dedicated to the memory of Ambassador Donald A. Mahley. The author thanks Ambassador R. F. Lehman for constructive feedback. The views and opinions presented here are those of the author and do not necessarily state or reflect those of the US government or Lawrence Livermore National Security, LLC. This work was performed under the auspices of the US Department of Energy by Lawrence Livermore National Laboratory under contract no. DEAC52-07NA27344, document release no. LLNL-JRNL-833178.

10.1126/science.abo6380

Science

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Science, 376 (6591), • DOI: 10.1126/science.abo6380

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