CONVERGENCE AT THE INTERSECTION OF CHEMISTRY AND BIOLOGY - IMPLICATIONS FOR THE REGIME PROHIBITING CHEMICAL AND BIOLOGICAL WEAPONS

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EXECUTIVE SUMMARY

Since the adoption of the Biological and Toxin Weapons Convention (BWC) in 1972, chemical and biological weapons have been treated as two separate categories of weaponry, and their treaty regimes (the BWC and the Chemical Weapons Convention or CWC) have evolved in different ways. The reasons for this separation were pragmatic; a reflection of what could be achieved at the time (the ban of biological weapons) and what needed more time and effort to negotiate (the chemical weapons ban). The separation of the regimes governing these two types of weapons also reflected differences in science and technology underlying the two regimes. This is where today's trends in the life sciences gain significance. Convergence at the intersection of chemistry and biology (also involving other disciplines, in particular mathematics, information technology and engineering) is increasingly blurring the lines between chemical and biological weapons arms control. This has been recognized by the OPCW (the implementing agency of the CWC) as well as the Member States of the BWC and its Implementation Support Unit (ISU). Contacts between the two institutional settings have evolved and some of the science information base they use to assess emerging risks is being shared. Added to this co-operation as part of policy and implementation, there have also been suggestions for convergence in the legal sphere, in the development of a common framework that would bring chemical and biological weapons back together under one single norm. This paper argues that the development of common and increasingly overlapping approaches to implementation and norm maintenance at international level is inevitable. This is despite the differences between the two treaties and despite the range of practical difficulties that legal convergence between them would imply. Such processes have in fact begun at the level of national implementation in several countries already. However, how this process can be managed at the international level and what legal and institutional solutions would need to be developed remains to be seen. The paper argues, however, that it is time to begin thinking about such opportunities as well as to identify constraints and conditions that would have to be met to make this process acceptable and politically feasible. The paper does not suggest the creation of a shared legal framework or any form of institutional fusion, but instead argues in favour of better process coordination and joint programming along similar lines as approaches already adopted within environmental law and as part of humanitarian responses to natural events. It presents five specific recommendations:

1. Establishment of an informal group of experts to monitor and review how developments in science and technology change patterns of production and trade in the evolving industrial

uses of biologically-based science and how they affect uses of chemical and biological materials.

2. Organisation of a series of expert meetings, or a project group, to review technical options for international verification and alternative compliance management measures in the area of overlap between the CWC and the BWC.
3. Organisation of international discussion fora to discuss the state of the art in risk identification, assessment and management with regard to developments at the intersection between chemistry and biology that are important for CB arms control and disarmament.
4. Continuation of informal information exchanges and contacts between the ISU and the OPCW, including through the SAB.
5. Development of coordination procedures and, where possible, joint projects involving the OPCW, the ISU and other relevant international agencies (for example: WHO, OIE, UNITAR, Interpol) to deal with implementation issues related to activities at the overlap between the two treaties.

1. INTRODUCTION

Throughout history, chemical weapons (poisons used as means of warfare) and biological weapons (disease used as a means of warfare) have been considered together under international law. As disease theory evolved during the nineteenth and twentieth century, many practical aspects related to their use and to protection against them began to separate. However, despite this separation humanitarian and arms control law continued to treat them as one category of weaponry. This changed in 1972 when the Biological and Toxin Weapons Convention (BWC) was concluded whilst negotiations of the Chemical Weapons Convention (CWC) continued for another two decades. The reasons for this regime split-up were pragmatic: after more than a decade of discussions and negotiations in the Geneva Disarmament Forum[1] it had become clear, at the end of the 1960s, that banning chemical weapons would require complicated negotiations. This was because agreements had to be reached on contentious issues (of which there were many), as well as a need to work out all the details necessary to make the treaty viable (including its scope and comprehensive nature, and the way in which it could be verified). Furthermore, the existence of chemical weapons stockpiles in military arsenals meant that a global treaty banning chemical weapons needed to make provisions for their destruction and for the elimination of their production facilities under stringent international verification. On the other hand, a global ban on biological weapons was achievable: there were no recognized stockpiles of biological weapons (which also meant that the verification of the elimination of production facilities and stockpiles of biological weapons was not essential); biological weapons had not been integrated into the military doctrines of the two major military alliances of the time (the Warsaw Treaty Organization and NATO); their military value remained doubtful; and the absence of a verification system was not seen as a serious impediment to BW disarmament.

The regime separation also reflected differences in science and technology underlying the two types of weapons. On the one hand, there was chemistry and the chemical industry – a mature industry that had been evolving for more than half a century. Chemicals manufacturing and trade are foundations of national economies and important drivers of development. Any ban on chemical weapons needed to take account of the potential inherent in this industry for the development and production of new types of chemicals at industrial scale – amongst them chemicals with toxicological, chemical and physico-chemical properties that might make them potential candidates for new chemical warfare agents. Without providing assurances through verification that legitimate chemical plants and trade were not being used as a cover for clandestine chemical weapons

[1] The Geneva Disarmament Forum was initially called the Eighteen-Nations Disarmament Committee or ENDC, later the Conference of the Committee on Disarmament or CCD, and today the Conference on Disarmament or CD).

production, a treaty banning chemical weapons would not be practicable.

A biological industry comparable to the chemical industry, on the other hand, and one that reached beyond the traditional types of products manufactured by biological processes, had yet to emerge. Traditional biological processes (e.g., fermentation) and agents (e.g., yeast) were used by the food and drinks industry, and vaccines and antibiotics were developed and produced using traditional biological growth techniques. From an arms control perspective, however, the risks associated with these well-established technologies were considered moderate given the limited military and strategic value of biological weapons as perceived at the time. Research with microbiological agents found practical applications in medicine and agriculture, but the industry that provided the active ingredients of medicines, pesticides and other biologically-active molecules was either extracting them from natural sources, or it was the chemical industry that supplied synthetic analogues. Recombinant DNA work was only just beginning and the use of genetically modified organisms in an industrial production environment had yet to be established. There was no agreement on whether verification in the biological field was even possible. But on-site verification was not seen as a precondition to a treaty banning the acquisition and possession of biological weapons—the disagreement over whether verification was feasible was of little practical relevance.

The development of two distinct regimes that followed, with different characteristics and approaches to managing the risks of science and technology under arms control perspectives, has so far not caused any practical problems. The CWC and the BWC have their own procedural mechanisms and implementation culture, separate review mechanisms to take account of advances in science and technology, distinctly different approaches to compliance management,[2] and different institutional frameworks to manage the relations among their respective States Parties.

This is where today's trends in the life sciences gain significance. Convergence at the intersection of chemistry and biology (as well as convergence with other disciplines, in particular mathematics, information technology and engineering) is increasingly blurring the lines between the sciences that underlie the two treaties. The technologies used in industry are beginning to reflect this convergence, and the classical distinction between a synthetic chemical industry and an industry based on extracting biologically active ingredients from natural sources such as plants or

[2] The term “compliance assurance” is also often used in the literature. However, that term has a strong bilateral connotation (one party assuring the other of its treaty compliance). In multilateral treaty regimes, a range of other bilateral and multilateral procedures can be brought to use to resolve non-compliance concerns, including traditional procedures for the settlement of dispute, information exchanges and reviews, other fact finding mechanisms including as appropriate verification measures, and other institutional procedures to clarify situations and compel a party that has been found non-compliant to reestablish full compliance. This paper uses the term “compliance management” whenever the intention is to include in the concept mechanisms that reach beyond mere information exchanges and fact finding.

microorganisms is disappearing, with industry increasingly utilising biological and biologically mediated process for the manufacturing of chemical and biochemical products.

Such developments raise several questions: Should this convergence in science, technology and industrial manufacturing also lead to changes in chemical and biological weapons arms control? How will the regimes respond to these changes in the S&T environment, and should there also be convergence in the treaty regimes?

To understand the implications of Chem-Bio convergence for global arms control and disarmament, it is first necessary to recall the nature of the two regimes, and also to explain in some more detail what convergence actually is and how it affects risks related to chemical and biological warfare.

2. The Existing Treaty Regimes

2.1 The Biological and Toxin Weapons Convention of 1972 (in force since 1975)

The BWC compels its States Parties never in any circumstances to develop, produce, stockpile or otherwise acquire or retain biological and toxin weapons.[3] It also prohibits any direct or indirect transfer of biological and toxin weapons to anyone, as well as any assistance, encouragement or inducement of any State, group of States or international organisation to manufacture or otherwise acquire them.[4] It requires the destruction or diversion for peaceful purposes of all biological and toxin weapon.[5]

The Convention does not itself stipulate a prohibition of the use of biological and toxin weapons, but it does invoke the provisions of the 1925 Geneva Protocol for the Prohibition in War of Asphyxiating, Poisonous or other Gases, and Bacteriological Methods of Warfare (the 1925 Geneva Protocol), which contains such a prohibition.[6] It is the common understanding of the States Parties of the BWC that any use of a biological or toxin weapon would imply a violation of the BWC.[7]

Although the BWC does not define "biological weapons" and "toxin weapons", the understandings adopted by the States Parties of the BWC at successive Review Conferences make it evident that

[3] BWC Art. I.
[4] BWC Art. III.
[5] BWC Art. II.
[6] BWC Art. VIII.
[7] Additional agreements reached by Review Conferences relating to each article of the Convention, Section III (Article I), paragraphs 8-12, available at http://www.unog.ch/80256EDD006B8954/(httpAssets)/EBB7A76E3DC19651C1257B6D003A0028/$file/BWC%20&%20Additional%20Agreements%20Post%207RC.pdf. For the latest understanding see the Report of the Seventh Review Conference, Part II: Final Declaration, Article I, paragraph 3, available at http://www.unog.ch/80256EDD006B8954/(httpAssets)/E7D8D6E2C5258849C1257B6E0033A1D3/$file/BWC_CONF.VII_07.pdf

the prohibitions are comprehensive. Thus at the Seventh Review Conference in 2011 the States Parties reaffirmed the common understanding that the Convention is comprehensive in its scope and that "all naturally **or artificially created or altered** microbial and other biological agents and toxins, as well as their components, **regardless of their origin and method of production and whether they affect humans, animals or plants**, of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes, are unequivocally covered by Article I" (emphasis added).[8] The BWC uses a concept called the *General Purpose Criterion*, which links the concept of these weapons to "types and quantities [of microbial or other biological agents, or toxins whatever their origin or method of production] that have no justification for prophylactic, protective or other peaceful purposes." It also includes in the term weapons, equipment and means of delivery designed to employ such agents or toxins for hostile purposes or in armed conflict.[9]

For implementation, compliance monitoring and compliance management, the BWC relies on:

- measures to be implemented by its States Parties[10]
- consultative mechanisms at bilateral level or involving the United Nations[11] including a complaint procedure with the UN Security Council[12]
- five-yearly Review Conferences (the last – Seventh - Review Conference took place in 2011)
- an intersessional process of consultations and information exchange (with a meeting at expert level and a subsequent, diplomatic meeting of the BWC States Parties each year),
- a number of politically-binding measures agreed over the years, such as confidence-building measures of information exchange concerning certain activities and facilities that might raise compliance questions.[13]

There is no implementing agency for the BWC at the international level, and negotiations towards such a body failed in 2001 after the United States withdrew its support for the negotiations towards

[8] Final Document of the Seventh Review Conference of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, BWC/CONF.VII.7 (13 January 2012), Section II (Final Declaration), Article I, paragraph 3.
[9] BWC Art. I.
[10] BWC Art. IV.
[11] BWC Art. V.
[12] BWC Art. VI.
[13] For an overview on the different measures agreed see the BWC website managed by Implementation Support Unit at www.unorg.ch/bwc.

a Protocol that would have established such a body and created a verification system and other institutional structures to manage the implementation of the treaty at the international level. Instead, the States Parties of the BWC started a process of intersessional meetings between the Fifth and Sixth Review Conference, and in 2006 decided to set up an Implementation Support Unit (ISU) of three professional staff to support the BWC States Parties with regard to administration but also by rendering substantive support. Today, this ISU assists the annual expert and diplomatic meetings as well as the review conferences of the States Parties, supports the respective Chair in his/her work, manages the system of confidence building measures and assists States Parties in their national implementation of the Convention through consolidating and maintaining details of domestic measures relevant to the Convention, maintaining a list of national points of contact and acting as a clearinghouse for national implementation assistance and the implementation of Article X on international cooperation and assistance.[14]

The need to review scientific and technological developments is acknowledged in the treaty text of the BWC. In Article XII it is stated that:

> 'Five years after the entry into force of this Convention, or earlier if it is requested by a majority of Parties to the Convention by submitting a proposal to this effect to the Depositary Governments, a conference of States Parties to the Convention shall be held…..Such review shall take into account any new scientific and technological developments relevant to the Convention.'

Since the First Review Conference, the review of advances in science and technology as part of Review Conferences has become a general practice of the States members of the BWC.

In the words of the BWC website:

> "Biological science and technology has advanced exponentially since the signing of the Convention in 1972. Although the Convention is uniquely broad and bans 'microbial or other biological agents, or toxins, whatever their origin or method of production,' it is vital to stay informed about relevant advances in science and technology in order to identify potential breaches of the Convention. For instance, the fields of chemistry and biology are increasingly converging, blurring the distinctions between chemically-synthesized pathogens and organically-produced chemicals. On the other hand, similar scientific advances can also be of benefit to the Convention in that they can improve vaccines and disease diagnosis, for example. Nonetheless, the technology surrounding the BWC is inherently dual-use, demonstrating the importance of recognizing the fine line between peaceful and malevolent uses."[15]

The BWC recognises its common roots with the international efforts to ban chemical weapons. Firstly, it contains an undertaking of its parties to continue negotiating towards the adoption of a

[14] For details see www.unog.ch/bwc.

[15] See http://www.unog.ch/80256EE600585943/(httpPages)/7CD9879E9CE09EFDC1257AC500309AA7?OpenDocument .

Chemical Weapons Convention at the earliest possible date.[16] Secondly, its prohibitions extend to toxins, which are chemicals in nature. This creates an overlap in the scope of the two treaty instruments.

Since the Seventh Review Conference in 2011, the review of advances in science and technology and the assessment of their impact on the functioning of the BWC has become a Standing Agenda Item of the intersessional BWC process. In this context, developments at the intersection between biology and chemistry have drawn particular attention. Looking back to the Seventh Review Conference, the ISU summarised seven trends that it and the BWC States Parties consider important with regard to assessing the impact of advances in science and technology on the BWC:

> "convergence between disciplines; increasing understanding of the underlying principles and mechanisms of the life sciences; shifting focus of priority areas within commercial biotechnology; a greater geographical distribution of capacity; open science; and media, perceptions and interactions with society. New data on these trends continues to become available. … One additional trend that can be identified is an increased use of research collaborations. As biology becomes more dependent upon advanced technologies, scientists are working together more closely to get access to the 'barrage of high-end equipment that no one laboratory can afford'…".[17]

At the meeting of experts in August 2013, a side event was organised jointly by the ISU and the OPCW to discuss convergence issues, as well as issues related to education and outreach. This was an indication of the beginning, of an albeit limited, institutional engagement between the BWC and CWC processes and implementing bodies, to discuss issues in science and technology that affect both regimes. It followed less formal contacts, for example the appointment in 2011 of an officer of the ISU in his individual capacity as member of the OPCW SAB's temporary working group on convergence.[18]

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[16] BWC Art. IX.

[17] BWC Implementation Support Unit: *Advances in Science and Technology Related to the Convention*, BWC document BWC/MSP/2013/MX/INF.1 (3 June 2013), Section B, paragraph 4.

[18] There has also been some limited institutional engagement. In June 2013, Piers Millet from BWC-ISU participated as a guest speaker at the 20th session of the OPCW SAB. OPCW, BWC-ISU, and WHO presented a joint outreach event discussing science and technology issues after the final day of the Biobricks Foundation's Sixth International Meeting on Synthetic Biology (SB6.0) at Imperial College in London in July 2013. At the BWC Meeting of Experts in August 2013, introductions to the temporary working group on education and outreach (by the SAB Chair) and the temporary working group on convergence (by the OPCW science policy adviser) were presented to the plenary along with an overview of the OPCW SAB (by Stefan Mogl as a presentation of the Swiss delegation). The OPCW participated in a side event on science and technology at the 2013 BWC Meeting of States Parties. In the same meeting, Stefan Mogl presented an overview of the work of the TWG on convergence to the plenary session. Communication by Jonathan Foreman (OPCW).

2.2 The Chemical Weapons Convention of 1993 (in force since 1997)

The CWC followed the BWC after a further 20 years of discussions and negotiations: its text was adopted by the UN General Assembly in 1992; it was opened for signature in Paris in January 1993; and after four years of preparatory work it entered into force on 29 April 1997.

In terms of scope of prohibitions, basic undertakings and definitions, many of its provisions mirror those of the BWC: it prohibits the development, production, stockpiling, retention, acquisition, and transfer of chemical weapons,[19] requires that the States Parties destroy their CW stockpiles within agreed time frames,[20] and refrain from assisting, encouraging or inducing anyone to commit acts in contravention of the CWC.[21] In addition, however, the CWC also contains an explicit prohibition of the use of chemical weapons,[22] and it requires States Parties to eliminate (destroy or convert to purposes not prohibited) its CW production facilities within agreed time frames.[23]

As in the BWC, the definition of chemical weapons is based on a *General Purpose Criterion*. All toxic chemicals and their precursors qualify as chemical weapons *unless* they are intended for purposes not prohibited under the CWC, and *only* as long as their types and quantities correspond to these purposes.[24]

But in terms of implementation and institutional approach, the CWC takes a path fundamentally different from the BWC. At the national level, it explicitly requires its States Parties to implement administrative and regulatory measures needed to ensure that toxic chemicals and their precursors cannot be used for purposes prohibited by the CWC,[25] including the adaptation of their penal legislation to enforce the CWC within their jurisdiction, and it requires them to designate or establish a National Authority.

At the international level, the CWC established an implementing body (the Organisation for the Prohibition of Chemical Weapons or OPCW) as a forum for consultation and cooperation among the States Parties, supported by a Technical Secretariat that is tasked to implement a wide range of verification measures in regard to chemical weapons disarmament, the verification of the non-production of chemical weapons in the chemical industry, and special inspections to deal with suspected non-compliance situations (challenge inspections to resolve concerns about possible non-compliance, and investigations of the alleged use or threat of use of chemical weapons).

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[19] CWC Art. I.1(a).
[20] CWC Arts. I.2 and IV.
[21] CWC Art. I.1(d).
[22] CWC Art. I.1(b).
[23] CWC Arts. I.3 and V.
[24] CWC Art. II.1(a).
[25] CWC Art. VI.2 and VII.1.

The CWC, also has a strong foundation in science and technology, and advances in these fields and in the industrial manufacturing of relevant chemicals therefore need to be monitored and assessed regularly to ensure the continuing viability of the treaty. It is to this end that the CWC requires the Director-General to establish a Scientific Advisory Board (SAB) to provide specialised advice to him or her, and through him/her to the policy-making organs of the OPCW (the Executive Council and the Conference of the States Parties) and the States Parties, on such new developments.

This SAB has been working since 1998; it has met once or twice annually to prepare regular reports on its work. In addition, the SAB has prepared a special report for each of the three Review Conferences held so far by the OPCW. The SAB works in temporary working groups that address particular issues, ranging from narrow subjects (for example ricin production, saxitoxin) to broader subject areas that affect the CWC's operation (for example, sampling and analysis).

Although the terms "convergence" did not appear in SAB reports before its submission to the Second CWC Review Conference in 2008,[26] the SAB began to address issues at the intersection between chemistry and biology right from the start of its work. Three issues are of particular relevance for this discussion: the production of ricin, the transfer of saxitoxin, and the coverage of biologically mediated processes under the provisions for "other chemical production facilities".

Ricin: Ricin is one of two toxins listed on the Schedules of the CWC. It was included as an example of a toxin that had actually been weaponised and used as a weapon.[27] In 1999, the SAB was requested to provide advice on what exactly the entry "ricin" in Schedule 1 of the CWC encompasses and how its production ought to be accounted for. In its response, the SAB noted that ricin was a protein (a polypeptide of approximately 62 kDa molecular weight) contained in different varieties of the castor plant, *Ricinus communis*, and that its molecular structure varies in degree of glycolisation, between different castor bean plant families, and even within the same plant. Different ricin isoforms are known and there are differences between them in terms of chemical analysis, structure and toxicology. The common feature in terms of chemical structure is that all isoforms are made up of an A and a B chain coupled by a disulphide bridge.[28] It is this A-S-S-B

[26] OPCW, Note by the Director-General: *Report of the Scientific Advisory Board on Developments in Science and Technology*, OPCW document RC-2/DG.1 (28 February 2008).

[27] For a summary see Dana A. Shea and Frank Gottron: *Ricin: Technical Background and Potential Role in Terrorism*, Congressional Research Service Report for Congress 7-5700 (RS21383), 21 December 2010.

[28] OPCW: *Report of the Second Session of the Scientific Advisory Board*, OPCW document SAB-II/1 (23 April 1999), Annex I. The SAB subsequently clarified that certain ricin-like structures under investigation as anticancer drugs, and differing in structure by an additional linkage between recombinant A and B chains in the form of short peptide chains, should not be covered by this understanding. It recorded that "All forms of ricin originating from Ricinus communis, including any variations in the structure of the molecule arising from natural processes, or man-made modification designed to maintain or enhance toxicity, are to be considered ricin as long as they conform to the basic 'native' bipartite molecular structure of ricin that is required for mammalian toxicity, i.e. A and B chains linked only by a disulfide bond (A-S-S-B). Once the inter-chain S-S bond is broken or the protein denatured, it is no longer

configuration that is critical for the coverage of the molecule under Schedule 1 of the CWC. Once broken, the molecule leaves the CWC accountancy area. Castor oil plants, as a consequence, should not be subject to the CWC's procedures under Schedule 1 as the SS bond is broken in one of the early processing steps.

Saxitoxin (STX): This is the other toxin listed in Schedule 1 of the CWC – it had been included in Schedule 1 given its history as a toxin that had actually been weaponised.[29] It is one of several toxins that cause paralytic shellfish poisoning (PSP), a potentially deadly poisoning caused by contamination of certain molluscs such as mussels, clams and oysters with toxins produced by certain types of algae ("red tides").[30] For reasons of food safety, shellfish intended for human consumption therefore must be tested for these toxins. Initially, the question that arose was whether the CWC requirement to notify each transfer of a Schedule 1 chemical 30 days in advance of transfer could be eased to allow for transfers of STX reference standards in test kits for PSP on shorter notice. This was resolved through a "change" of the provision of paragraph 5 of Part VI of the CWC's Verification Annex: a new paragraph 5bis now allows for notification of small amounts (5 milligrams or less) of STX for medical/diagnostic purposes at the time of transfer.[31] But subsequently, the SAB also started reviewing what exactly was to be understood by "Saxitoxin". The ambiguity resulted from the CAS number assigned to this entry in the CWC (35523-89-8, which is the number for saxitoxin hydrate. The SAB observed that:

> "this differs from the CAS number (35554-08-6) for saxitoxin hydrate dihydrochloride salt, which is the form of saxitoxin that was previously weaponised on a small scale (as TZ). In fact seven CAS numbers have been assigned to saxitoxin hydrate (free base), its optical isomers, and various salts. … The view of the SAB was that the form of saxitoxin that was weaponised (dihydrochloride salt) should be covered by Schedule 1, and that all salts should be declarable. It should be noted that it is the salts of saxitoxin that have good long-term stability, but the hydrate free-base does not."[32]

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ricin." See RC-3/DG.1, paragraph 80.

[29] Laboratory Spiez: *Fact Sheet Saxitoxin (mytilotoxin; shellfish toxins; STX; PSP)*, Swiss Federal Departement ofDefence, Civil protection and Sport (20 July 2012), see http://www.labor-spiez.ch/en/dok/fa/pdf/fact_sheet_saxitoxin_e_07_2012.pdf .

[30] The causative organisms are Gonyaulacoid dinoflagellates. See, for example L. Fleming, 'Paralytic Shellfish Poisoning', NIEHS Marine and Freshwater Biomedical Sciences Center, available at <http://www.whoi.edu/redtide/page.do?pid=9679&tid=523&cid=27690>. Some freshwater cyanobacteria also produce STX, but probably using a synthetic pathway that has evolved independently from that of the dinoflagellates; see Jeremiah D. Hackett et al. "Evolution of Saxitoxin in Cyanobacteria and Dinoflagellates", Mol. Biol. Evol. Volume 30 , Numner 1 (20130, pp. 70-78, doi: 10.1093/molbev/mss142.

[31] Change to Section B of VA-Part VI, effective 31 October 1999, pursuant to UN, 'Acceptance of Amendment for a Change to Section B of Part VI of the Annex on Implementation and Verification ("Verification Annex")', Depositary Notification C.N.916.1999.TREATIES-7 (8 October 1999); together with the correction to the change to Section B of VA-Part VI, effective 9 March 2000, pursuant to UN, 'Change to Section B of Part VI of the Annex on Implementation and Verification ("Verification Annex") of the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction: Acceptance of Corrections to the Amendments', Depositary Notification C.N.157.2000.TREATIES-1 (13 March 2000). The SAB

[32] SAB Report to the Third CWC Review Conference, OPCW document RC-3/DG.1, paragraph 78 (29 October 2012).

Subsequently, the SAB recommended an extension of this exemption to transfers of STX and ricin for medical/diagnostic as well as analytical purposes (no action has been taken on this recommendation as yet by the States Parties).[33]

At the same time, the SAB also recognised that for both toxins, genetically modified organisms could be adapted to their production. The SAB stated that:

> "[in] the case of ricin, and bacterial toxins such as botulinum, production from culture of the natural organism is reasonably efficient. This is not the case for saxitoxin, which must be harvested from marine organisms. In theory, metabolic pathway engineering could be used to produce saxitoxin but, at the present, would require an extensive and covert research programme."[34]

This growing potential for manufacturing biochemicals (including toxins and bioregulators) that were hitherto only accessible through extraction from natural sources (which is expensive, time consuming and has small yields) by alternative synthetic, biological or mixed production processes has become a primary concern with regard to conversion trends. This concern does not merely relate to biomolecules such as toxins, but more broadly to toxic and precursor chemicals relevant to the CWC.

To this day, the resources required to scale up production methods using metabolically engineered yeast to industrial levels remain significant. The problems to be resolved include the development of processes that generate large amounts of biomass with a consistent yield and functionality of the desired chemical product. Secondly, the product must then be purified in ways that preserve its pharmacological activity whilst leading to economically interesting amounts of product.[35]

Biologically mediated production of discrete organic chemicals (DOCs):[36] Already in 1999, the SAB addressed the question of whether the term "production by synthesis" used in the CWC's provisions pertaining to "other chemical production facilities" (i.e., chemical plant sites that that produce unscheduled discrete organic chemicals or unscheduled DOCs) would also include manufacturing processes that involved biological or biologically-mediated processes. For scheduled chemicals, that issue is clear from the CWC itself,[37] and was further clarified by a decision of the

[33] RC-3/DG.1, paragraph 11.
[34] RC-3/DG.1, paragraph 39.
[35] For an example see "Method for the industrial purification of biologically active phytotoxins", patent application WO 2010109386 A1 (published 30 September 2010).
[36] DOCs are covered under Article VI and Part IX of the Verification Annex of the CWC. They differ from scheduled chemicals in that they are not specifically listed in the CWC but covered through a generic definition. The purpose is to capture for verification purposes organic chemical production facilities that may have the technological capacity to manufacture scheduled chemicals without actually being involved in such production.
[37] See the definition of "toxic chemicals" in Article II.2 which includes the terms "This includes all such chemicals, regardless of their origin or of their method of production, and regardless of whether they are produced in facilities, munitions or elsewhere".

OPCW Conference of States Parties.[38] With regard to DOCs, the situation was less clear-cut. The SAB noted that "from a scientific standpoint, it is no longer possible to make a clear distinction between 'chemical' and 'biological and biologically mediated' processes. The emphasis should be on the product rather than on the process."[39] Despite this recommendation, the OPCW was unable to agree on a common guideline and differences in implementation practice emerged between States Parties. These differences were noted again in the run-up to the Third Review Conference in 2013, except that at this point in time the industrial landscape had begun to change. In 1999, the SAB recommendation had little practical impact, 14 years later, biological and biologically mediated processes had moved from a niche business closer to mainstream industrial chemicals production. There are today production plants using biologically mediated processes in a number of countries, typically operating at a scale of multiple tonnes per year.[40] These plants mostly remain below the declaration threshold of 200 t/a of aggregate production of DOCs per plant site. Some estimates suggest that by 2020, some 10 per cent of the world's production of chemicals may be biologically mediated.[41] In the words of the SAB,

> "[the] convergence of chemistry and biology is evident in the increasing commercial production of chemicals through biologically mediated processes, and the chemical synthesis of simple replicating organisms, biological parts, and agents of biological origin such as bioregulators and toxins."[42]

On the same issue, the Stockholm International Peace Research Institute (SIPRI) observed:

> "while … the increasing convergence between chemistry and biology is of direct relevance to the CWC, it is principally the advances in technology (i.e. the developments in process chemistry and chemical process technology) that would have a measured impact on the CWC verification regime. Advances in the underlying science usually have no immediate bearing on the effectiveness of the industry verification system: activity at larger-scale production facilities matters more than activity at the laboratory or bench level. However, developments in science and technology can affect national implementation requirements with respect to the amounts and types of toxic chemical present and used in different aspects of society, as can related risk-management strategies at the national level."[43]

The above examples show that issues related to convergence at the intersection of chemistry and biology have a direct bearing on CWC implementation processes already today. To better understand what is actually happening and how convergence may affect the CWC regime, the SAB established a temporary working group on convergence between chemistry and biology. Contacts

[38] C-II/Dec.5 (5 December 1997).
[39] SAB-II.1, paragraph 2.3.
[40] Communication Jonathan Foreman, OPCW.
[41] See "Biomass chemicals to be competitive in 10-15 years", *ICIS Chemical Business*, April 2-15, 2012 edition, page 24
[42] RC-3/DG.1, Part A, paragraph 5.
[43] M. Daoudi et al. *The Future of the Chemical Weapons Convention – Policy and Planning* Aspects, SIPRI Policy Paper No. 35 (April 2013), p.17.

were established between this temporary working group and the BWC's ISU, and an officer of the ISU became member of that group. But before addressing the question of how the arms control system should respond to these convergence trends, it is important to state more clearly what the term "convergence" encompasses.

3. WHAT IS "CHEM-BIO CONVERGENCE"?

ChemBio convergence, for want of a better word, is part of a wider transformation in the life sciences. In fact, the intimate relationship between chemistry and biology predates the present debate about convergence in the life sciences. One could argue that at the molecular level, biology is just another form of chemistry (as, for example, indicated by the term "biochemistry"), and that chemistry has always been one of the tools that biology has used to test its hypothesis and investigate natural phenomena.

The initial convergence discussion in the life sciences in fact had little to do with chemistry: it concerned the introduction of concepts and methodologies from the engineering sciences into biology. Much of this has been subsumed into the concepts of "synthetic biology". Schmidt observed that "[one] of the aims of synthetic biology is to make biology easier to engineer. Major efforts in synthetic biology are made to develop a toolbox to design biological systems without having to go through a massive research and technology process."[44] Rand characterised this convergence as a "multidisciplinary technology revolution".[45] These convergence trends encompassed biology, chemistry, engineering, informatics / advanced computing, and mathematics (modelling and simulation), and were enabled by a number of technologies including the Internet, cloud computing, combinatorial synthesis combined with high-throughput screening, and more generally speaking automation of key techniques used in life science research. But from an arms control perspective, a particularly interesting aspect was that these developments directly affected the overlap between regulatory systems that had been set up to control and manage risks associated, respectively, with chemical and biological weapons. In an arms control context, then, the on-going convergence in the life sciences was perceived as a convergence between chemistry and biology.[46]

On the part of biology, our understanding of biological systems and processes has reached a level where engineering principles and mathematical modelling and simulation make it possible to separate biological processes and components, analyse their individual functional properties, and to

[44] M. Schmidt *Diffusion of Synthetic Biology: A Challenge to Biosafety*, Syst. Synth. Biol. DOI10.1007/s11693-9018-z, Springer OpenAccess (June 2008).

[45] *The Global Technology Revolution. Bio/Nano/Materials Trends and Their Synergies with Information Technology by 2015*, Prepared for the National Intelligence Council, Santa Monica: RAND (2001).

[46] For an early overview see: Alexander Kelle (Ed.) *The Changing Scientific and Technological Basis of the CBW Proliferation Problem – A Workshop Report,* Queen's University Belfast (13-14 January 2006).

attempt to modify these functionalities in a directed and predictable manner. This leads into what we call today "synthetic biology", a term that covers a wide range of experimental activity, from attempts to develop standardised biological building blocks ("biobricks") with well-defined functionality that can be connected in biological circuits to perform desired functions all the way to the construction of new or the reconstruction of existing biological organisms such as viruses or bacteria. At the same time, the knowledge expansion that results from mathematical modelling and simulation, combined with enhanced computation capacity, have spurred a new field called "systems biology", an approach by which "biological questions are addressed through integrating experiments with computational modelling and theory, in re-enforcing cycles"[47] in an attempt to move closer towards predicting biological functionality from first principles.

In chemistry, several drivers are making biological processes attractive as alternatives to traditional chemical synthesis for certain types of chemicals: the search for alternative raw materials to address potential future shortages of mineral oil and gas led to work on new "platform chemicals" (chemical feedstock); the need for renewable sources for fuel production stimulated the production of biofuels; and finally the scarcity of certain natural products that are used in medicine (which limited the capacity for extraction and workup from natural materials and sometimes resulted in high prices) stimulated the search for alternative technologies that combined biological with chemical process as an economically attractive alternative.

Chem-Bio convergence received attention from the arms control community initially because of this potential effect on the manufacturing of chemical as well as biological products. The traditional barriers that have separated the manufacturing technologies for biological agents and toxins (the reliance on functionalities of biological systems such as replication and metabolism) from the industrial manufacturing of chemical products by synthesis in production equipment such as glass and steel vessels began to disappear. As observed by the SAB, "[the] convergence of chemistry and biology is evident in the increasing commercial production of chemicals through biologically mediated processes, and the chemical synthesis of simple replicating organisms, biological parts, and agents of biological origin such as bioregulators and toxins."[48]

The SAB in its report to the Third Review Conference listed a number of relevant developments that are affected by, or indicative of, this convergence. [49] These can be summarised as follows:

- Biologically mediated production of bulk chemicals is increasing driven by the increasing cost of petroleum-based feedstock and the shift towards greener chemistry;

[47] See: http://www.bbsrc.ac.uk/web/FILES/Publications/systems_biology.pdf.
[48] RC-3/DG.1, Part A, paragraph 5.
[49] RC-3/DG.1, paragraphs 28-46.

- Biocatalysis in bulk and fine chemicals production is predicted to increase in high-volume manufacturing of commodity chemicals as well as low volume production of specialty chemicals and pharmaceuticals;
- Whilst biologically mediated production of toxic chemicals appears not to have any particular advantage over past technologies, important developments are occurring in the production of more complex chemicals in modified biological systems (production of proteins and low-molecular mass non-protein natural products; production of recombinant proteins by genetically modified yeast or bacteria in bioreactors; biofarming using transgenic organisms; production of complex non-protein chemicals using metabolic pathway engineering[50]);
- Application of synthetic biology to the manufacturing of toxic chemicals may in the future become an avenue to monitor;
- Chemical synthesis of biological (replicating) systems,[51] made possible by technological advances, reductions in the cost of equipment and materials, and the emergence of specialised services such as DNA synthesis that trade over the Internet;
- Chemical synthesis (or manufacturing by metabolic pathway engineering) of peptides and other bioregulators, or more metabolically resistant analogues and/or chemicals that mimic the function of bioregulators may become relevant in the context of possible developments towards new incapacitating agents;
- Developments that could improve defences against chemical weapons (e.g., bioscavengers to treat nerve agent poisoning, modified enzymes as treatments or decontaminants)

In the long run, however, ChemBio convergence is more than a change in the production landscape for biological and chemical products. As the discussion above has shown, convergence is allowing a larger number of people to manipulate biological systems faster, cheaper and more easily, thus increasing the potential range of practical applications of biological processes and systems. In the longer run, and driven by the utilisation of engineering principles and the application of mathematical modelling and simulation perhaps more than by convergence between chemistry and biology alone, biology may be transferring itself from a primarily descriptive into a more and more predictive science. In the genetic field, this trend is clearly visible already. The combination of cheaper and better gene sequencing methods and equipment, the development of tools that allow to

[50] An example is the production of the anti-malarial drug Artemisinin, normally extracted from the plant sweet wormwood, *Artemisia annual*, using a genetically modified E. coli bacterium. See Vincent J.J. Martin et al. *Engineering a mevalonate pathway in Eschirichia coli form production of terpenoids,* Nature Biotechnology Vol. 21 No. 7 (July 2003), pp. 796-802.

[51] To be precise: at this stage, the synthesis relates to the manufacturing of the key parts of replicating systems (DNA, RNA, proteins) whilst the production itself takes place in a system of biological origin.

swap, insert, extract, activate or silence genes, and the growing capacity to synthesize large gene sequences or even entire genomes more accurately, has already led to new insights into the functioning of biological systems and the (re)creation of fully-functioning small biological organisms at the level of viruses and bacteria.

There remain of course limits to the accuracy that can be achieved by gene synthesis today, which is why in commercial applications, it is common practice to synthesize smaller DNA segments which are then incorporated into existing microorganisms, for example for directed evolution and subsequent production of products such as vaccines.

With regard to more complex biological systems and functionalities, progress is slower and less predictable given the "fuzziness" of life processes and the complexity of biological organisms. How fast and far the transition of biology from a descriptive to a predictive science will actually go, and how close it may move towards the synthesis of complex, fully-functioning artificial life forms, is difficult to say. It is already clear today, however, that such studies are enhancing our understanding of some of the fundamental regulatory systems of the human body. With a shift in interest from chemical and biological agents that aim at killing or disabling people, to more subtle forms of toxicity that manipulate complex biological functions such as perception, mood, performance, alertness and the like, knowledge of the functioning of regulatory circuits in the brain and elsewhere in the human body and of the biomolecules involved therein is growing fast. This growing understanding of biological functionality may become itself a source for the discovery of new types of candidate biochemical agents, if the existing ban of *any* kind of chemical or biological weapon were allowed to weaken and the norms underlying the two treaty regimes were not applied in a robust manner to prevent the development of such new types of weapons.

4. Convergence Calls for Management of Risks and Benefits

Both the OPCW Conference of the States Parties and the BWC Meeting of the States Parties have concluded that the current advances in science and technology can potentially bring huge benefits for mankind, but that they at the same time carry certain risks for the existing arms control norms in the field of chemical and biological warfare, and that these risks therefore need to be managed carefully.

From an arms control perspective, a demand for better risk management is firstly a call for appropriate action by the States and by the international organisations and mechanisms they have created. The primary objective of disarmament and arms control remains to manage the conduct of States and their interaction in the international system, aiming at the reduction and where possible

abolition of the means of warfare, in particular of those that cause excessive suffering or mass casualties. Diplomacy and the negotiation of agreements and treaties to minimise security risks, the faithful application of these agreements (*pacta sunt servanda*), the adaptation of existing agreements to new challenges, and compliance management therefore remain primary and necessary avenues to address these emerging risks.

The trends in research, development and production that characterise the Chem-Bio convergence, however, are not solely, and perhaps not even primarily, driven by government activity. Governments often remain major funders of research and development, including in areas of potential dual-use applications. But private institutions including industry today undertake much of the research and development in the life sciences. This has been recognised by the Seventh Review Conference of the BWC in the context of the implementation of Article X of the BWC.[52]

Equally important is that the environment within which this work takes place has changed significantly. A key enabler is the Internet as a place for communication, planning and project management, as a device for information sharing and for commerce, and as a depository of biological (and other) data. Related thereto is the fall in the cost of equipment (e.g., desktop DNA and protein synthesisers and sequencers) and materials (e.g., DNA, genomes, proteins).[53]

All this means that the work at the intersection of chemistry and biology is becoming increasingly globally distributed. Drivers for this progress include strong commercial market forces (not merely in the health care and pharmaceutical sector but increasingly also in other areas such as energy production, food supply and safety, managing the impact of global warming, and even such "remote" sectors as the entertainment industry with regard to simulation and modelling of complex systems), government investment to counter deliberate outbreaks of disease, and demands from public health.[54]

There do remain significant roadblocks to such interdisciplinary endeavours, including barriers in the transfer from the acquisition of data to the generation of knowledge, the importance of tacit knowledge, and bottlenecks in such areas as biological data generation that are useable in modelling, as well as limits in computation capacity. At the same time, there also is the chance of

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[52] Seventh Review Conference of the States Parties of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction: *Final Document of the Seventh Review Conference*, Document BWC/Conf.VII/7 (13 January 2012), II. Final Declaration, paragraph 52.

[53] For a recent analysis see, for example, Kavita M Berger et al: *Bridging Science and Security for Biological Research: International Science and Security*, Meeting Report (AAAS, Associations of American Universities, Associations of Public and Land-grant Universities, and Federal Bureau of Investigation), AAAS Washington DC (February 2013).

[54] National Research Council: *Life Science and Related Fields: Trends Relevant to the Biological Weapons* Convention, Washington DC (2011), Section 5.1.

serendipitous discovery and the potential for the synergistic effect of simultaneous progress in multiple fields.

In this changing environment, governments have less ability to control and minimize proliferation risks by top-down action than in the past. Several factors are important for this:

- The "time compression" between new discoveries and their application in society;
- The shift in the life sciences from a physical to an information science;
- Limits to the freedom governments have to utilize such traditional tools as export controls (in particular if applied to intangibles);[55]
- The global distribution (trade in equipment and materials, collaboration), which limits the ability of any one government to monitor and control research in this field and its distribution;
- The increasing recognition that , promoting global technology diffusion - a declared aim of the arms control regimes - can lead to security benefits through greater interdependence, transparency and governance;
- Sensitivities in industry with regard to confidentiality and the impact of controls on their trade;
- Unpredictability of how and where exactly new discoveries from life science research will find practical application.

As a consequence, a new methodology of managing risk is needed, one that involves a broader range of actors ("stakeholders") and a more distributed and participatory network approach to monitor and assess S&T advances with regard to their impact on CB arms control, and to devise strategies that minimise these risks.[56] Such multi-layered risk management approaches have been discussed with regard to specific fields of activity (for example DNA synthesis and synthetic

[55] See as an example recent "gain-of-function" H5N1 experiments. The Dutch government did require an export license for the publication of Ron Fouchier's paper on airborne transmission of a genetically modified A/H5N1 influenza virus in Science in June 2012. The use of the export licensing procedure was found appropriate by the Haarlem District Court upon appeal, but Fouchier's employer Erasmus MC Rotterdam has appealed with the Netherland's Court of Appeal. In the meanwhile, the European Society for Virology (ESV) has supported Fouchier's position in a letter to the president of the European Commission, José M. Barroso, pointing to their view that the procedure was at odds with academic freedom; see Martin Enserink, *Dutch fight over H5N1 export rules moves to Court of Appeal*, Science News (4 November 2013). In December 2013, on the other hand, more than 50 internationally renowned scientists under the umbrella of the Foundation for Vaccine Research wrote a separate letter to Barroso, taking issue with a number of claims in the statement submitted by the ESV. The signees did not take a position on the issue of export licensing, although they stated that they understood the Dutch government's concern. See: The Foundation for Vaccine Research, *Response to Letter by the European Society for Virology on "Gain-of-Function" Influenza Research and Proposal to Organize a Scientific Briefing for the European Commission & Conduct a Comprehensive Risk-Benefit Assessment* (18 December 2013), available at http://news.sciencemag.org/sites/default/files/media/Letter%20to%20Barroso_0.pdf.

[56] For a discussion see, for example, Caitriona McLeish and Ralf Trapp, *The life science revolution and the BWC - Reconsidering the science and technology review process in a post-proliferation world*, Non-Proliferation Review Vol. 18, No. 3 (2011), pp. 527-543

genomics),[57] or more generally for dual use work in the life sciences.[58]

At the same time, the increasing global distribution of science and technology in the life science field and the new forms of collaboration, facilitated by the Internet, open access databases and publications, and a significant drop in the cost of conducting activities in this field have led to the emergence of what might be understood as a "post-proliferation" world.[59] As the distance in time grows from the CB programmes of the Cold War era (and as progress is being made in eliminating these past programmes), risk perceptions are shifting towards the *potential* that new discoveries might be used for malevolent purposes. In the OPCW, this is reflected in a "transition discussion" of how the organisation's priorities should shift from a primary focus on the elimination of chemical weapons stockpiles and production facilities to the prevention of the re-acquisition of chemical weapons of any kind, with a corresponding shift of resource allocations related to verification activities.[60]

In such a "post-proliferation world", risk management must be based on a broader governance approach and in addition to the different parts of governments that are concerned should also involve other actors, coming from industry, the academic and R&D communities, and civil society. It has been observed that:

> "[in] such a world, traditional models of proliferation control are certain to fail, and the traditional top-down government approaches no longer seem appropriate. From a broader regulatory perspective, the role of governments is changing. The state alone is no longer able to control the way that life sciences discoveries are used. The circumstances beg instead for a governance system that brings together all stakeholders—science, industry, government, and the public—and broadens as well as deepens the basis for compliance with the safe and responsible conduct and utilization of science, thus supporting the norm against biological weapons. The time is ripe not only to think about how future advances in the life sciences enterprise should be monitored and evaluated, but also about what governance structures need to be developed to mitigate any risks associated with these advances while maximizing their benefits for humankind."[61]

In such a scenario of shifting from traditional government-centred to a broader governance

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[57] Michael S Garfield et al., *Synthetic Genomics: Options for Governance*, Rockville MD: J.Craig Venter institute ;Washington DC: Center for Strategic and International Studies; Cambridge MA: Massachusetts Institute of Technology (October 2007).

[58] An example is Jonathan B Tucker (editor): *Innovation, dual use, and security – managing the risks of emerging biological and chemical technologies*, The MIT Press Cambridge, Massachusetts and London, England (2012).

[59] That may not be the case for cutting edge innovative research that must, amongst others, take account of regulatory frameworks and at the same time continually invent new tools in order to facilitate integration of innovative research into technology. It may also not apply to knowledge, information and materials specifically related to chemical or biological weapons design.

[60] See the *Report of the Advisory Panel on Future Priorities of the Organisation for the Prohibition of Chemical Weapons*, Note by the Director-General – Technical Secretariat document S/951/2011 (25 July 2011). See also Ralf Trapp *The OPCW in transition: from stockpile elimination to maintaining a world free of chemical weapons* Disarmament Forum (UNIDIR), volume 1 (2012), pp. 41-53.

[61] Caitríona McLeish & Ralf Trapp: *The Life Sciences Revolution and the BWC*, The Nonproliferation Review, Vol. 18 No. 3 (2011), pp. 527-543

approach to manage emerging S&T risks, one also needs to ask whether the traditional barriers between the two regimes (CWC and BWC) can be sustained, or whether (and if so at what stage in the development of science and technology and the associated industrial base) these barriers will in fact become a hindrance to effective risk management.

5. Regime Convergence at Multiple Levels?

How to deal with Chem-Bio convergence from an arms control perspective has been discussed now for several years. Proposals range from enhancing the CWC verification system,[62] to bringing the regimes together under a joint framework convention,[63] to increased interaction between technical experts in chemistry and biology.[64] The SAB observed in its report to the Third CWC Review Conference that:

> "[the] convergence of chemistry and biology is leading to an increased overlap between the Convention and the Biological Weapons Convention (BWC), for example, in the areas of toxins and bioregulators, which risk falling between the two conventions.[65] The SAB has initiated an exchange between experts on the Convention with experts from the BWC in its TWG on the convergence of chemistry and biology. The Board recommends that the interaction between experts on the two treaties, and between the Secretariat and the Implementation Support Unit of the BWC is strengthened. Discussions on the effects of convergence on these two conventions should be supported by technical reviews in other fora."[66]

Regime convergence can happen at the level of national policy, legislation and administration, and it can happen at the level of international treaty law or the use of interagency mechanisms. National and international processes of regime adaptation may take palace in synchrony, or there may be pressures towards regime convergence at the national level that are resisted at the international level, or new international frameworks may be created before national systems are adapted.

It is perhaps too early to say which direction the adaptation of the CBW arms control regime may take in response to Chem-Bio convergence but early indicators seem to suggest that there are

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[62] See for example Jonathan B. Tucker, "The convergence of biology and chemistry: implications for arms control verification", *Bulletin of the Atomic Scientists*, 66 (2010) 56-66.

[63] M. Dando, *The Merits of a Biochemical Framework Convention*, Bulletin of the Atomic Scientist (1 October 2008), available at http://thebulletin.org/merits-biochemical-framework-convention. See also L. Sydnes: *Update the Chemical Weapons Convention*, Nature Vol. 496 (4 April 2013), pp. 25-26.

[64] Note by the Director-General, *Response by the Director-General to the Report of the Scientific Advisory Board on Developments in Science and Technology for the Third Special Session of the Conference of the States Parties to Review the Operation of the Chemical Weapons Convention*, OPCW document RC-3/DG.2 (31 January 2013), paragraph 7.

[65] The phrase "risk falling between the two Conventions" is perhaps somewhat misleading. Both Conventions base their prohibitions on a General Purpose Criterion, and both cover toxins. That ensures that all such materials (including materials that have yet to be discovered) are covered. The problems that may arise at the interface between the two Conventions therefore are more likely related to deficiencies in practical implementation of the requirements of the two treaties, or confusion about which specific regulations apply to a particular case. That can in particular affect national implementation system.

[66] RC-3/DG.1, paragraph 6.

pressures in some countries towards bringing affairs together at the national level whilst there are a number of countries who oppose regime convergence at the international level, both in terms of institutions and related implementation processes, and in terms of legal instruments.

5.1 The National Level

At the national level, there are a number of early indicators that point towards the feasibility, and perhaps desirability, of bringing together the systems that prohibit chemical and biological weapons and that manage and control relevant research, development and industrial activities.

Examples are:

- In many countries, a shared basis of science and technology expertise that supports government efforts in these two fields;
- In some countries, attempts to bring together the legal and administrative systems, for example through penal and implementing legislations that combines the requirements of both treaties, or through implementing bodies that carry responsibility for both treaties;
- Outreach to relevant industries with regard to treaty compliance and internal compliance-assurance mechanisms[67] involving companies that operate in both fields;
- The streamlining of export control systems to use single control lists and harmonised licensing and risk assessment procedures (for example the European Union single list of dual use goods).

An interesting new approach was taken with the establishment of CBRN Centres of Excellence and the associated regional secretariats and "National CBRN Teams" in the countries participating in these centres, as an EU funding mechanism for regional projects in specific areas of capacity building.[68] These efforts, of course, reach beyond Chem-Bio convergence and address the full spectrum of CBRN risks, including also radiological and nuclear issues. Nevertheless, the mechanism appreciates that in addition to issues that require a sectoral, specialised approach to deal with certain types of risks, there also is a need to a more overarching, integrated approach to connect these different sectoral mechanisms and actors. This innovative approach carries much promise provided that the participating countries can break down the "silo mentality" that so often prevents effective collaboration across different branches of government.

The *rationale* for this approach is explained thus:

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[67] Industry has well-established and very effective mechanisms to roll out compliance assurance procedures, train its employees in such areas as regulatory compliance, and do so on a global scale. A pertinent example is the chemical industry's Responsible Care® initiative, for details see http://www.icca-chem.org/en/home/responsible-care/.

[68] This initiative is funded under the EU's Instrument for Stability, priority one (CBRN risk mitigation). For details see http://www.cbrn-coe.eu .

> "While knowledge and expertise needed to mitigate CBRN risks of criminal, accidental or natural origin are available at national, regional and international levels, these resources are often not effectively implemented. Lack of coordination and preparedness at national levels and fragmentation of responsibilities within a region can have dramatic consequences: non-state actors trying to acquire CBRN materials or expertise will exploit this situation, and an incoherent response will broaden the impact of a CBRN incident. This is why the European Union is putting in place a framework providing for cooperation and coordination between all levels of government and international partners."[69]

This approach builds on; the creation of "National Teams", networking among national stakeholders in government, industry and other relevant segments of society, a thorough national assessment of requirements, assets and needs to manage the risks in the CBRN area, and the development of balanced and realistic national action plans. The Centres of Excellence initiative adds to this a dimension of regional coordination and collaboration, access to international actors and knowledge centres, and of course the possibility of developing partnerships and of receiving/providing technical assistance for capacity development.

The general approach of developing a whole-of-government approach is attractive in particular in the overlapping area of chemical and biological risk management, including with regard to the implementation of the two Conventions.

The convergence of chemistry and biology involves transformations in the industrial base which is regulated by the two treaty regimes. Such transformation makes certain convergence in national level implementation inevitable. This convergence may not necessarily be understood to require a merging of administrative and legislative mechanisms and institutions. . It may also be understood to require other solutions such as: improved networking and collaboration between government bodies, inter-ministerial coordination mechanisms, task forces and similar tools. Such policy decisions will be affected by a host of factors such as resources, bureaucratic tradition, legislative context and the exact nature of the industrial landscape in the country. Regardless of the means of response from government, Chem-Bio convergence appears to be a long-term trend, and therefore inevitably will leave its mark on how governments organise themselves to address and manage the risks associated with biological and chemical weapons. In the context of such change, much can be gained by involving scientists and engineers in the development of policies and in particular by engaging with those who can bring new ideas, and who can understand and communicate the nuances of technology development.

5.2 The International Level

[69] www.cbrn-coe.eu/AboutCoE.aspx .

How such regime convergence processes at the national level affect the international regimes is less certain. The OPCW as well as the ISU have recognized convergence as an issue that affects the implementation of their respective treaties. Informal contacts between the two institutional settings have evolved and some of the science information base is now shared. But there also have been suggestions for convergence in the legal sphere, for developing a common legal framework that would bring chemical and biological weapons back together under one single international norm.

On the part of the international science and technology community, such a combined process of review and assessment has already begun. Examples are the inputs by international science unions and the Inter Academy Panel to the review conferences of both treaties: much of the science base mobilised for these reviews, and the mechanisms used to organise international review workshops, conduct reviews of the state of the art in relevant parts of science, undertake assessments with regard to impact on the arms control treaties in question, and develop recommendations to the treaty communities are in fact shared commodities.

A wealth of knowledge and analysis has gone into these studies. A weakness of such reviews by the science community often is that they focus on what is cutting edge but remain less informed about how scientific discoveries are transferred into technologies and used in industry. Yet, understanding how new science integrates into new technology is essential for informed risk assessment. This is why in future such reviews, a stronger interaction with industry will be important.

At the level of State-to-State relations and the work of international organisations, however, the process is more complicated (and some States will deny any need to bring the respective implementation processes under the BWC and the CWC closer together). Several factors stand in the way of a more intensive interaction of the two treaty regimes:

- The profound differences in how the treaties work at the international level (with strong institutionalisation in form of the OPCW and a verification system in place on the one hand, and a small and limited-in-mandate ISU and no verification system on the other);
- The existing differences in institutional context (the OPCW as the dedicated international agency dealing with CWC implementation and chemical weapons disarmament;[70] in the

[70] As chemical weapons disarmament is been completed, however, the CWC finds itself increasingly in a situation not unlike the BWC today: although still the only global CW disarmament agency, it will have to interact with a large number of other organizations that have mandates and deliver programme activities in areas adjacent to those of the OPCW – an example is the overlap of programme activity in what is today called “chemical security”. This trend has also been recognized in a recent study of the UN’s Counter-terrorism Implementation Task Force: CTITF, *Interagency Coordination in the Event of a Terrorist Attack using Chemical or Biological Weapons or Materials,* CTITF Publication Series (New York, August 2011).

BWC there is a broad spectrum of international agencies that have partial mandates and interests related to the BWC and its implementation – the ISU with regard to managing the BWC processes, but also WHO in the context of the International Health Regulation 2005, OIE, FAO, Interpol and other organisations, and UN ODA with regard to the UN Secretary General's mechanism to investigate alleged breaches of the 1925 Geneva Protocol);

- The difference in adherence to the two treaties (190 States Parties and 2 signatory States to the CWC[71] as compared to 170 States Parties and 10 signatory States to the BWC[72]), which could cause legal and institutional friction (decision making, budgetary authority and legal authority, for example) with regard to those countries that adhere to one treaty but not the other. This, of course, is less and less an issue given the progress that both treaty regimes have been making towards universal adherence. There remain however some countries that have joined one treaty but not yet the other.

A key difference remains the absence of a verification system under the BWC. It is true that there has been movement towards more active compliance management under the BWC in recent years. Information exchanges amongst the parties (in the form of confidence building measures, and informal exchanges during the intersessional process, for example through voluntary reporting of national implementation measures taken by the parties) have improved, and the ISU has actively helped in this process. But the system still falls short of compliance management as known from other treaty regimes, and verification as one of the most effective measures of compliance management remains out of reach for the BWC.

A simple return to the verification procedures negotiated but not agreed during the Protocol negotiations would probably be impractical in many respects, given the changes that have taken place in science, technology and industry since the Protocol negotiations collapsed. If a BWC verification system were to be developed today, a new approach would be needed. This may involve a review of control lists of agents and equipment, but also a more basic review of objectives, verification approaches, tools, opportunities and constraints. At this stage, however, the political will to develop such a new concept of BWC verification remains lacking.

In the absence of a functioning BWC verification system, combining international implementation processes of the two treaties may only be realistic in areas of marginal relevance to compliance management. What has happened so far can best be characterised as limited information sharing.

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[71] OPCW Technical Secretariat, Office of the Legal Adviser: *Status of Participation in the Chemical Weapons Convention as at 14 October 2013*, OPCW document S/1131/2013 (14 October 2013).

[72] See http://www.unog.ch/80256EE600585943/(httpPages)/7BE6CBBEA0477B52C12571860035FD5C?OpenDocument .

Examples include the appointment of an ISU staff member to the temporary working group on convergence of the OPCW's SAB, the presence of the SAB temporary working group at the BWC annual meeting of experts and the meeting of the BWC parties in 2013, and a number of informal science-oriented meetings that brought the expert communities of the two treaties together.

Such information sharing is, of course, important in itsown right. It can help creating awareness about the implications of Chem-Bio convergence, it can support the science and technology review process of the two regimes, it can facilitate the utilisation of the shared expertise basis, and it can keep both systems informed about what the other regime is doing in practice.

This can also lead into joint action regarding outreach and awareness raising activities directed towards "shared" stakeholder communities, for example in academia and industry. Such outreach activities are important to promote internal compliance assurance measures adopted by the manufacturers and users of chemical or biological products and technologies.

Certain coordinated activities have also been agreed by the OPCW and the BWC-ISU to promote universalization of the regimes, as well as in the field of implementation assistance.[73] But institutional hurdles before such joint action remain, and so do the significant differences in institutional capacity and the political and legal concerns about "trespassing" into territory that, despite or perhaps because of the overlap between the two treaties, the other treaty regime may claim as its own.

At the same time, it is worth noting that the CWC's challenge inspection mechanism applies to the investigation of any non-compliance concern under the CWC, including those that involve toxins and bioregulators. These types of biochemicals are also covered under the BWC. There is, thus, an overlap between the two treaty regimes that could lead into practical collaboration, or at least shared responsibility, when it comes to dealing with an alleged use of such biochemicals as weapons.

But unless a more practical move can be made towards a broader and closer collaboration of the two treaty systems, there may be a risk that over a period of time, *both* treaties may become self-limiting, backward looking and losing their connection to the real world of the life sciences and their application in industry.

[73] For example, there is an agreement in principle between the Head of the ISU and the Director-General of the OPCW on delivering joint universalization messages. Each entity is encouraged (and has agreed) to take opportunities when interacting with states not currently party to the other treaty to provide basic information, encourage them to join and facilitate their contact with the relevant organization. Equally, there has been a promising start to coordinated activity on implementation assistance. Prime examples are back-to-back implementation / universalization events in Angola in April 2013 and a similar planned event in Myanmar. Information provided by Piers Millet, BWC Implementation Support Unit.

6. THE ROAD AHEAD - RECOMMENDATIONS

A first step has been made with regard to creating institutional and substantive links between the processes and institutions related to implementing, respectively, the CWC and the BWC. Information channels have been opened up and some coordination between the ISU and the OPCW, as well as the science organisations working with them, has emerged.

The process of Chem-Bio convergence and the revolution in the life sciences are only just beginning. The pressures on the international arms control system are, at the moment, still rather modest. Traditional approaches (calls for more effective national treaty implementation, more efficiency in CWC verification, application of export controls) still seem to work. The question is how quickly and profoundly the overall industrial landscape will change, and in which way the industry's science and technology base will evolve.[74]

For the time being, an argument can still be made that:

- For the CWC and its implementation systems, what matters most is how the verification system can be most effectively applied to the industrial-scale production of chemicals that could be used as precursors or toxic agents (i.e., doing more of the same, but better), whilst
- For the BWC, what matters is how national implementation systems can be developed and applied to manage the risks associated with the advances in life science research as well as the associated industries, with respect to possible hostile uses of biology including as weapons, and how any compliance concerns can be clarified between the States Parties.

But projections about the advances in the life sciences and their application in different parts of society tend to conclude that we are at the beginning of a scientific *revolution*. If that assessment is correct, we should not merely expect an acceleration of the pace of progress, but also sudden and unexpected "leaps" (non-linear progress in unpredictable ways and directions) with unanticipated consequences flowing in their wake.

Diplomatic processes to adapt arms control and security arrangements to new requirements, as a rule, are far too slow to cope with rapidly changing circumstances. Negotiating new treaties, renegotiating existing agreements or other formal ways of adapting international legal systems are unlikely to be able to respond in a timely way to such type of change. One could argue that this actually speaks in favour of compliance management systems that are less formally regulated than

[74] For a discussion see also: Ralf Trapp: *Research, development and production: impact and challenges for the future*, in: Jean Pascal Zanders (ed.) *The future of the CWC in the post-destruction phase*, EU ISS Report No. 15 (2013), pp. 15-27.

the CWC's routine verification system. But that would only hold true if such other mechanisms were in fact effectively utilised on a regular basis.

If the arms control system that we have inherited from the Cold War does not adapt, the existing instruments and institutions may over time find themselves dealing with issues that are no longer a primary security concern whilst the challenges that are emerging are either left to "national improvisation" and political alliance-building, or addressed by international actors and mechanisms that may not be fit for that purpose.

This calls for a strategy that prepares for more informal, yet nevertheless robust, multilateral mechanisms to adapt the existing systems. It will also require a higher degree of interaction between the different communities concerned (science, industry, security and diplomacy). To design such a strategy, some starting questions need to be asked and practical issues addressed:

- Some kind of monitoring and warning system is needed that not merely reviews what is happening in the life sciences and related disciplines including biology and chemistry, but that more specifically analyse how the *industrial basis* that makes use of these scientific advances is changing and how this affects the functioning of the two regimes, both nationally and at the international level. A first step in this direction has already been made with the recommendations submitted by the OPCW's SAB Temporary Working Group on Convergence. Such a mechanism should involve people who develop technology and understand how new sciences integrates into new technologies (including scientists, engineers, but also economists and financial experts), as well as arms control specialists;
- From a practical point of view, the important issue is which new scientific developments are brought forward to societal use involving chemical and biological materials. This inevitably must affect practical implementation measures implemented under the CWC as well as the BWC:
    - At the national level, government authorities, companies and other institutions working in the domain that is subject to both sets of regulations (CWC implementation as well as BWC implementation measures) will find themselves addressing similar practical issues at the same locations/facilities. That in itself is not unusual – regulatory requirements stemming from different legal requirements and that are applicable to the same industrial operation or product type are commonplace.[75] The key difference here is that both treaties,

[75] Chemical companies are already compelled to comply with a range of regulations and standards, for example emission standards for air and water, workplace safety standards, standards concerning the handling and treatment of waste materials, transportation requirements, standards that apply to the safety of their products including testing for certain impurities and contaminations, regulations pertaining to labelling of their products, regulations pertaining to

at the national level, require more or less the same types of compliance management measures. This is likely to raise questions with regard to burdens on industry that could be avoided, as well as unnecessary duplication of bureaucratic measures in government. This does not only apply to compliance measures concerning regulations and standards, but also to "softer" governance measures such as industry outreach, awareness raising in the research and academic communities, the development and application of codes of professional conduct, or the integration of CBW disarmament norms into education and teaching at schools and universities.

- Therefore, government, industry and civil society actors should have an interest in more effectively coordinating their activities to develop multi-layered governance approaches of risk management. In governments, it will be a challenge to overcome the traditional disconnect between different government bodies and move towards an all-government approach.[76]
- At the same time, putting in place effective and sustainable mechanisms to work with industry and the academic and research communities will be a challenge. This, however, will be necessary as countries address longer-term risks associated with these developments. Governments alone will not be able to identify, assess and manage these risks, nor are they likely to be able to reap the benefits of the scientific revolution in the life sciences to the full, unless they are able to connect to other stakeholders.

- At the international level, the context wherein compliance management, including verification, is being conducted will change. Calls for expanding CWC routine verification to cover certain types of chemicals that may be of growing concern (e.g., peptides) have already been made. But as CWC verification attempts to "encroach" onto territory that traditionally belonged to the BWC, the perceptions and interests (political, economic and security) that have led some countries to block moves towards BWC verification will inevitably get in the way of adapting the CWC verification system. It is not inconceivable that some of those who today call for more energetic adaptation of CWC verification to changes in science, technology and the chemical industry may tomorrow argue that routine verification at the intersection of chemistry and biology is both impossible and undesirable. This is why a new discussion is urgently needed to better understand the options and parameters of effective compliance management, and in that context the feasibility of international verification in the biological sector.

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their export, transfer, marketing and ultimately their disposal.

[76] An example for how such inter-ministerial and interagency collaboration can be developed is the formation of National CBRN CoE teams under the EU's new initiative to sponsor the setting up of regional CBRN Centers of Excellence. For details see http://www.cbrn-coe.eu/AboutCoE.aspx .

- At the same time, more appreciation will be needed for the need to ensure effective investigation of any non-compliance concerns (including in the area of toxins and bioregulators at the overlap between the two Conventions).
- Such a discussion may not be possible in the diplomatic context of the BWC intersessional process (or its review conferences) given the anathema attached by (at least) one major power to discussing verification under the BWC. It would also probably be difficult to conduct such a verification discussion in the context of the OPCW. It might perhaps even be counterproductive as motivations could easily be misunderstood as an attempt to shift the burden of verification and control technology transfers in an area that many countries see as vital for their development.
- There is therefore a need to find a different format[77] for discussing these issues, at least until the options and possible directions have become more clearly delineated. But it would be paramount that governments and industry are involved in such a conversation.
- Beyond verification, the existing treaty mechanisms for compliance management may come under pressure from continued institutional and process fragmentation. As science and technology expand into the area of overlap between the two treaties, international efforts to assess the associated risks for the arms control system should be brought closer together. Otherwise, there is a chance that some efforts to manage them will be duplicated whilst others fall through and are not taken care of by either the CWC or the BWC regime.
- Similarly, there are opportunities of joint activity that come under the wider implementation mandates of the two treaties, in such areas as providing assistance to States in implementation and capacity building. Such joint activities have begun, and will require careful interagency coordination.
- However, experience has also taught that calling for a "super-coordinator" who can bring all the different actors at the international level together and ensure effective collaboration, clear direction and leadership is not a feasible option. Not only is the existing system already too complex for any single agency or actor (including the UN) to be able to hold it all together, but also any attempt to create such a superstructure is likely to produce an inflexible and static system that is vulnerable to challenges and changes in the external environment – precisely the opposite of what the system is expected to deliver.

[77] For example, such discussions could start among States that have expressed an interest in BWC verification, as exploratory talks rather than as formal negotiations involving all BWC member states. Such informal talks should involve also experts from industry and think tanks / civil society. They could lead into practical pilot projects to test the viability of the options discussed. Such an approach could help clarifying objectives and technical options, and hopefully avoid overly politicized or divisive discussions.

- The approach that presents itself is one known from coordinating international environmental programmes as well as from emergency response: a form of process coordination where common rules are developed and used by the actors involved, who otherwise operate within their own institutional and legal context and mandate. Examples can be found in environmental law (Multilateral Environmental Arrangements),[78] in chemicals management (Inter-Organisational Programme for the Sound Management of Chemicals and the Strategic Approach to International Chemicals Management),[79] and in drugs control and international criminal law.[80]

These considerations lead to suggesting a series of recommendations, as follows:

Recommendation 1:

Establishment of an informal group of experts from the OPCW, the ISU, interested governments, industry and academia to monitor and review how developments in science and technology change patterns of production and trade in the evolving industrial uses of biologically-based science and how they affect uses of chemical and biological materials in society.[81] This would be a sort of technology monitoring exercise that should be repeated from time to time, and should involve a mapping of relevant changes and of how they relate to the requirements of the two treaties. A framework that has been used successfully in the past for such conversations is Pugwash – not as part of the regular work but in form of a dedicated project group.[82] Alternative approaches could be temporary project groups funded by interested funding organisations or States.

Recommendation 2:

[78] See http://synergies.pops.int/Home/tabid/813/mctl/ViewDetails/EventModID/8849/EventID/439/xmid/8753/language/en-US/Default.aspx.

[79] See http://www.who.int/iomc/en/ and http://www.saicm.org.

[80] See the UN Office of Drugs and Crime (UNODC) strategy for the period 2012-2015, adopted by ECOSOC as E/Res/2012/12, see https://www.unodc.org/documents/about-unodc/UNODC_2012_-_2015_Resolution_ECOSOC_merged.pdf .

[81] The OPCW SAB temporary working group on convergence has proposed a platform for this. Switzerland has announced a new series of biennial meetings to be held at Spiez laboratory that will cover these issues. The first meeting will take place 6-9 October 2014.

[82] An example from past practice was the series of Pugwash projects on chemical industry verification, many organized jointly with SIPRI. These projects led to a number of publications that had a direct impact on the negotiations of the CWC's industry verification regime – see SIPRI Chemical and Biological Warfare Studies, no. 4 and 5 (*The Chemical Industry and the Projected Chemical Weapons Convention*, Conference Proceedings volumes 1 and 2, 1986); no. 9 (S.J. Lundin, *Non-production by Industry of Chemical Warfare Agents – Technical Verification Under a Chemical Weapons Convention*, 1989), no. 11 (Thomas Stock and Ronald Sutherland, *National Implementation of the Future Chemical Weapons Convention*, 1990); no. 13 (S.J. Lundin (ed.), *Verification of Dual-use Chemicals under the Chemical Weapons Convention – the Case of Thiodiglycol*, 1991); no. 14 (Ralf Trapp, *Verification under the Chemical Weapons Convention: On-site Inspection in Chemical Industry Facilities*, 1992).

Organisation of a series of expert meetings, or a project group similar to recommendation 1, to review technical options for international verification and alternative compliance management measures in the area of overlap between the CWC and the BWC. Such a study should be informed by past work on a BWC Verification Protocol, current OPCW industry inspection practice, discussions in the OPCW SAB's temporary working group on verification, and the practices of other verification agencies (such as IAEA, CTBTO, and national regulatory agencies). But it should not be constrained or overly-directed by these practices and precedents, nor aim straight at the evaluation of the feasibility of verification measures proposed. Instead, such an exercise should start from basic principles (objectives, nature of the industry concerned and its activities, technical opportunities and constraints for verification, pros and cons of other compliance management measures). A possible example is the European Safeguards Research and Development Association (ESARDA) verification group that has been working on nuclear safeguards issues.[83]

Recommendation 3:

Organisation, from time to time, of international discussion fora (conferences, workshops) to discuss the state of the art in risk identification, assessment and management with regard to developments at the intersection between chemistry and biology that are important for CB arms control and disarmament, and/or with regard to CBRNe risk mitigation strategies at large. The purpose of such specialised meetings would be to further develop the methodology for risk assessment and to identify options for risk management in that particular area of science and technology, and to feed results back into the policy-oriented processes associated with the OPCW and the BWC intersessional process.

Recommendation 4:

Continuation of informal information exchanges and contacts between the ISU and the OPCW, including through the SAB. The SAB's TWG on convergence was a temporary structure; it would be desirable to come to more stable arrangements for information sharing and exchanges of experience, for example through an arrangement between the two secretariats based on a Memorandum of Understanding or by creating a permanent observer post for the ISU on the SAB. The OPCW Technical Secretariat has used the tool of making arrangements with other Secretariats through an MOU in the past when it had identified areas where long-term coordination was necessary – such arrangements remain informal and do not require the endorsement of the policy

[83] See https://esarda.jrc.ec.europa.eu .

making organs of the OPCW. They are therefore more flexible and can be adapted to evolving needs and circumstances.

Recommendation 5:

Development of coordination procedures and, where possible, joint projects involving the OPCW, the ISU and other relevant international agencies (for example: WHO, OIE, UNITAR, Interpol) to deal with implementation issues related to activities at the overlap between the two treaties.

The potential spectrum of such coordination mechanisms and joined activities is wide, and it may be politically convenient to start with such areas of implementation as

- *Exchanging experience* about fostering international cooperation in science, technology and industrial application of the life sciences, and potentially developing joint projects in this field;
- Developing *capacity building projects* in the field of protection against exposure to hazardous biological and chemical materials (whether caused by accidental or intentional releases);
- Development of *shared guidance documents and training materials* to promote appropriate practical measures in academia, research and industry to implement treaty requirements in different areas (safety, security, export controls, etc.);
- Development of *shared methodologies and tools for industry outreach* (including internal compliance assessment/management tools), and implementation of outreach projects together with interested States;
- Development of *shared methodologies and tools for other types of national implementation measures* (regulations, training, response mechanisms, etc.) that are relevant to both Conventions.

In the long run, such activities could lead into stable long-term coordination structures, for example in the form of an intergovernmental programme on safety and security in the life sciences that would involve multiple agencies at the international level,[84] or through the Centres of Excellence in CBRN risk mitigation that are being developed with support from the EU.

An alternative is the form of process coordination that has been developed by international agencies and organisations involved in humanitarian relief – this also could be a model for how broader coordination mechanisms could be developed.[85] Such a mechanism would be particularly suitable

[84] An example for such a combined process of an intergovernmental program and an international interagency coordination mechanism, in the field of environmental risk management, is the Intergovernmental Forum for Chemical Safety (IFCS) and the associated Inter-Organization Program for the Sound Management of Chemicals (IOMC) and the Strategic Approach to International Chemicals Management (SAICM).

[85] See the UNDAC mechanism as described at http://www.unocha.org/what-we-do/coordination-tools/undac/methodology-training .

for projects in the area of capacity building, provided that there is a system of effective needs assessment in place (see the experience from the National Profiles in chemicals management).

However, issues related to treaty compliance management would have to firmly remain under the auspices of the responsible treaty organisation as set out in their respective mandates.

No matter how the issue of Chem-Bio convergence will be taken forward and strategies be devised to maximise the beneficial effects it will have for humankind whilst curtailing any risks it may pose that might affect the relevance and operation of the two treaty regimes, it will be important that the *arms control community* takes responsibility for initiating this conversation and taking it forward. This conversation will be one among diverse communities with different objectives, perspectives and experiences. It is important that the arms control community reaches out to other stakeholders in industry, research and academia, and that the arms controllers themselves get better educated about what Chem-Bio convergence is, how it may affect the regimes that govern the prohibition of chemical and biological weapons, and what can be done about the risks involved.