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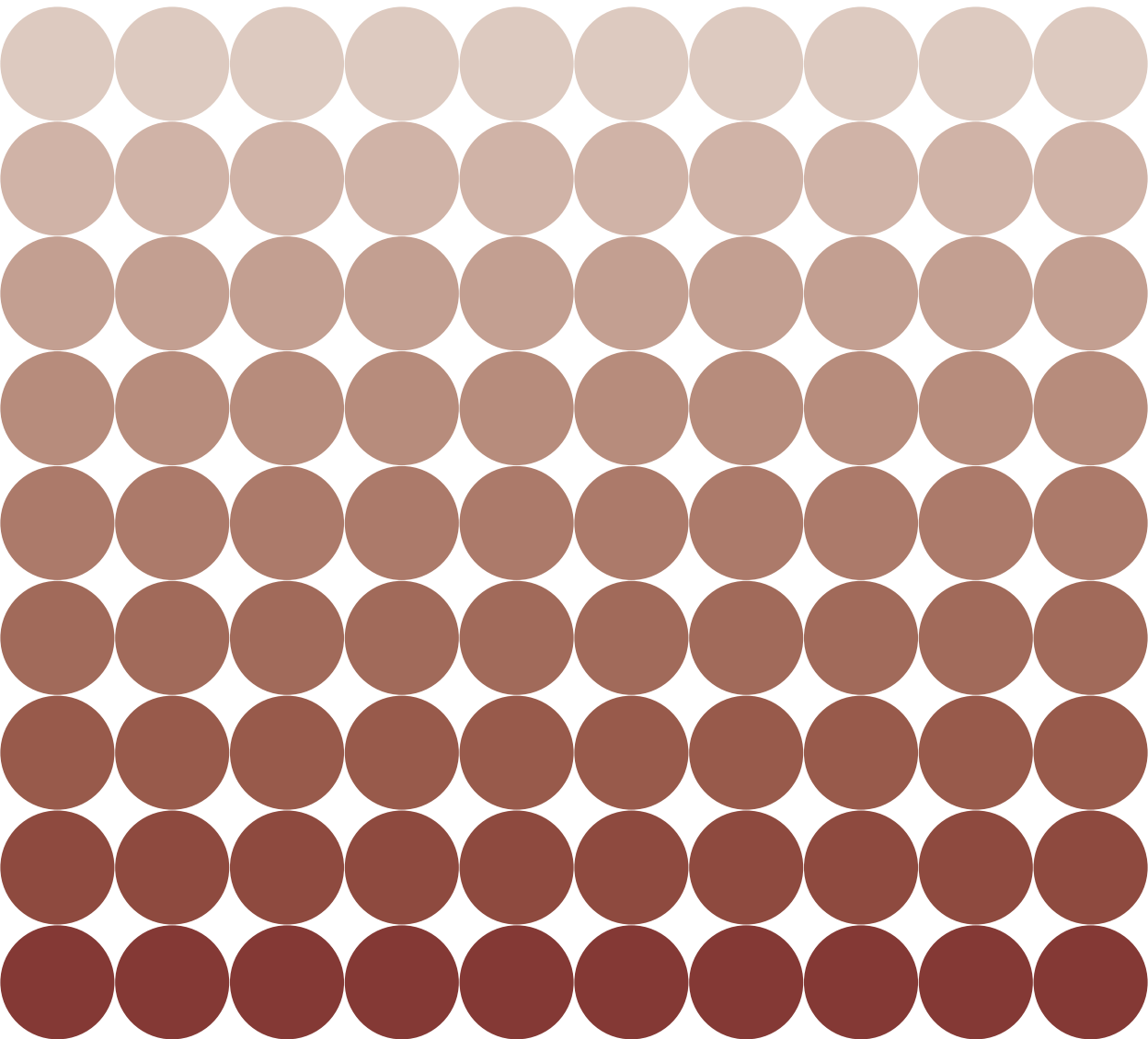
CHEMICAL AND BIOCHEMICAL NON-LETHAL WEAPONS

Political and Technical Aspects

RONALD G. SUTHERLAND



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Chemical and Biochemical Non-lethal Weapons

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SIPRI Policy Paper No. 23

RONALD G. SUTHERLAND

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All substances are poisons; there is none which is not a poison.
The right dose differentiates a poison and a remedy.
Paracelsus (1493–1541)

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Preface

Non-lethal weapons are intended to incapacitate personnel or materiel without injuring people. This Policy Paper describes and analyses biological and chemical substances that have the potential to be used as weapons or can improve the efficacy of other, more traditional, weapons. Potential loopholes in the international prohibitions against chemical and biological warfare (CBW) are presented together with practical, politically feasible and technically useful policy options. It is not a comprehensive legal review or an exhaustive survey of activities in the field of non-lethal weapons but offers valuable insights on an increasingly important topic.

The 1993 Chemical Weapons Convention and the 1972 Biological and Toxin Weapons Convention were negotiated with a limited number of 'traditional' CBW agents in mind that were developed as part of state programmes, but today we are probably witnessing a fundamental change in the view of what constitutes a CBW agent. A report by the US National Academy of Sciences (*Emerging Cognitive Neuroscience and Related Technologies*, 2008) warns of dangerous applications of cognitive neurosciences and related technologies (e.g. for drug development and surreptitious delivery as an aerosol). Such developments raise questions about how states and relevant institutions, such as the Organisation for the Prohibition of Chemical Weapons, implement international prohibitions against CBW. This work, by striking the right balance between scientific detail and reader-friendliness, will inform both the specialist and the generalist involved in policymaking on this emergent and complex issue.

I would like to express my deep appreciation to Professor Ronald G. Sutherland for preparing this Policy Paper. He has contributed to the work of SIPRI for more than 20 years and during that period has contributed to or co-edited numerous SIPRI publications and has provided expert advice and unstinting support for SIPRI's work, most recently as a member of our Governing Board. Thanks are also due to SIPRI editor Jetta Gilligan Borg, who edited the text into its final, smooth form; to Ronda Duke and Cynthia Loo, who typed the original version; and to Dr Ian Anthony, Dr Peter Clevestig and John Hart for their valuable comments and support.

Dr Bates Gill
Director, SIPRI
October 2008

Summary

The possibility that chemical or biological substances might be used for hostile purposes or as a method of warfare is of concern to those involved in ensuring that the international prohibition against chemical and biological warfare (CBW) is effectively implemented. The 1972 Biological and Toxin Weapons Convention (BTWC) and the 1993 Chemical Weapons Convention (CWC) are the principal international legal instruments against CBW. If any chemical or biological substance—including toxins and, in principle, various pharmacologically active drugs—were used for 'hostile purposes or in armed conflict' or as a 'method of warfare' it would constitute a violation of the BTWC and the CWC, respectively. The BTWC has weak verification mechanisms, while the CWC has quite strong verification mechanisms and procedures which are implemented by the Organisation for the Prohibition of Chemical Weapons (OPCW), located in The Hague.

This Policy Paper therefore focuses on the CWC. It also introduces the basic rationale behind the development and use of non-lethal weapons (NLWs), including to support counterterrorism and peacekeeping operations. Chemical and biochemical NLWs pose a fundamental policy challenge: how to reconcile the use of such weapons—which can reduce the number of deaths and casualties—with various other legal, ethical and political concerns. Such concerns include the possible misuse of NLWs to facilitate the killing of targeted individuals and the use of NLW research and development programmes as a cover for an offensive CBW capability or programme.

The Policy Paper analyses various terminology and provides an overview of select activities to develop NLWs and also of the development of standard riot control agents and criteria for their use. In some quarters there is concern that NLWs present a 'back-door' loophole (actual or potential) to the international prohibitions against CBW and this Policy Paper examines that concern. The paper concludes by recommending politically feasible steps for clarifying and responding to NLW-related issues. The CWC will remain central to consideration of issues related to non-lethal weapons.

Abbreviations

BTWC	Biological and Toxin Weapons Convention
BA	Bromoacetone
BZ	3-Quinuclidinyl benzilate
CA	Bromobenzylcyanide
CBW	Chemical and biological warfare
CN	Chloroacetophenone
CR	Dibenz[b,f][1,4]oxazepine
CS	Ortho-Chlorobenzylidene malononitrile
CWC	Chemical Weapons Convention
DM	Diphenylaminearsine
DNA	Deoxyribonucleic acid
FBI	Federal Bureau of Investigation
LSD	D-lysergic acid diethylamide
NLW	Non-lethal weapon
OC	Oleoresin capsicum
OPCW	Organisation for the Prohibition of Chemical Weapons
PS	Chloropicrin
RCA	Riot control agent

1. Introduction

International repugnance at the effects of chemical and biological weapons led to the banning of their use in warfare. However, scientific and political developments related to chemical and biochemical non-lethal weapons (NLWs) have continued, and these have implications for maintaining the effectiveness of international prohibitions.[1] While complete information about the number and scale of NLW research and development programmes is difficult to ascertain, their number and scope are expanding. The circumstances in which NLWs can be used are also becoming broader and more varied—partly because of continuing scientific and technological developments, such as those in the field of synthetic biology.

NLWs may be defined as 'weapons which are explicitly designed and developed to incapacitate or repel personnel, with a low probability of fatality or injury, or to disable equipment, with minimal undesired damage or impact on the environment'.[2] The US Department of Defense has defined NLWs as 'weapons that are explicitly designed and primarily employed so as to incapacitate personnel or material, while minimizing fatalities, permanent injuries to personnel and undesired damage to property and the environment'.[3] Agents that can be used for NLW purposes include riot control agents (RCAs), calmatives, malodorants and various types of disabling biochemical agents. Much of the initial work on these agents pre-dates World War II and was frequently an integral part of some states' chemical and biological warfare (CBW) programmes.

There is no consensus on how the 1972 Biological and Toxin Weapons Convention (BTWC) and the 1993 Chemical Weapons Convention (CWC), the two main international agreements prohibiting CBW, can or should address NLWs.[4] The parties to these conventions are generally reluctant to incorporate consideration of NLWs on a routine or formal basis because of possible concern about the appropriate cost, scope and level of intrusiveness that these regimes should have. There is also concern in some quarters about the possible placement of restrictions on counterterrorism, domestic law enforcement and peacekeeping operations. Nevertheless, NLW programmes constitute a potential loophole in the

[1] See the discussion of biochemical weapons in chapter 3 in this Policy Paper.

[2] North Atlantic Treaty Organization (NATO), 'NATO policy on non-lethal weapons', Press release, 13 Oct. 1999.

[3] US Department of Defense (DOD), 'Directive no. 3000.3: Policy for non-lethal weapons', Washington, DC, 9 July 1996, <http://www.dtic.mil/whs/directives/corres/text/d30003p.txt>, p. 2. See also US National Academies, National Research Council, *An Assessment of Non-lethal Weapons Science and Technology* (National Academies Press: Washington, DC, 2002).

[4] For summaries of the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction and of the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction see appendix A in this Policy Paper.

international prohibition against CBW. As such they demand further scrutiny and analysis.

Chapter 2 provides background information on NLWs, including legal considerations, technical and safety issues as well as an introduction to the types of such weapons, and the activities and programmes associated with them. Chemical agents that can be used as non-lethal weapons are discussed in chapter 3, while chapter 4 addresses disabling biochemical substances and synthetic biology. The conclusions and recommendations are presented in chapter 5.

2. Background

International prohibitions against CBW may be undermined by the development of non-lethal weapons, including through the development of doctrines and procedures for their use.[5] It is unclear what activities states may be taking to develop capacities to influence human physiology and mental states through the use of biological substances or chemicals.[6] This uncertainty is further heightened by the potential application of scientific and technological developments.[7] The international prohibition against CBW is based on the BTWC and the CWC. Other international law—including humanitarian law such as the rule against 'perfidy', the 'discrimination principle' and the principle of proportionality—is also of potential relevance.[8] Extensive literature exists on the technological developments and political implications of NLW programmes, much of it focused on the United States.[9]

The advantage of using NLWs could be significant: in the Viet Nam War the number of casualties caused by small guns was over 30 per cent.[10] However, there are concerns that 'non-lethal weapons may cause deaths either though deliberate or inadvertent misuse'.[11]

[5] Other terms for such agents are commonly used, including 'less-than-lethal agents' and 'incapacitants'. These terms may have different meanings and legal implications. See e.g. US Army, Marine Corps, Navy and Air Force, Air, Land, Sea Application Center, 'NLW: multi-service tactics, techniques, and procedures for the tactical employment of nonlethal weapons', Report no. FM 3-22.40, Fort Monroe, VA, Oct. 2007, <http://www.fas.org/irp/doddir/army/fm3-22-40.pdf>.

[6] See e.g. US Department of Justice, 'Solicitation: less lethal technologies', CFDA no. 16.560, Nov. 2007, <http://www.ncjrs.gov/pdffiles1/nij/sl000810.pdf>; and Committee on Military and Intelligence Methodology for Emergent Neurophysiological and Cognitive/Neural Research in the Next Two Decades, *Emerging Cognitive Neuroscience and Related Technologies* (National Academy of Sciences: Washington, DC, 2008).

[7] Phillips, A. P. and Robinson, J. P. P., 'The CWC and chemicals of biological origin', Paper presented at OPCW Academic Forum, The Hague, 18–19 Sep. 2007, <http://www.opcwacademicforum.org>.

[8] Herby, P., 'Protecting and reinforcing humanitarian norms: the way forward', eds A. M. Pearson, M. I. Chevrier and M. Wheelis, *Incapacitating Biochemical Weapons: Promise or Peril?* (Lexington Books: Lanham, MD, 2007) , pp. 285–89; and Kim, P., 'Between principles and absolutes: non-lethal weapons and the law of armed conflict', *Non-Lethal Capabilities Facing Emerging Threats: Conference Proceedings, Second European Symposium on Non-Lethal Weapons, 13–14 May 2003* (Fraunhofer Institute of Chemical Technology: Pfinztal, 2003), pp. 2-1–2-15,

[9] See e.g. *Non-Lethal Capabilities Facing Emerging Threats* (note 8); and eds Pearson, Chevrier and Wheelis (note 8). Hundreds of primary documents on US research in this area were obtained by the now defunct Sunshine Project. Most are available at <http://www.sunshine-project.org/>.

[10] Statistics for the Viet Nam War indicate that of the 58 193 total casualties some 18 518 were caused by small arms fire (i.e. 31.8%). National Archives and Records Administration, 'Statistical information about casualties of the Vietnam War', Feb. 2007, <http://www.archives.gov/research/vietnam-war/casualty-statistics.html> .

[11] Hart, J., Kuhlau, F. and Simon, J., 'Chemical and biological weapon developments and arms control', *SIPRI Yearbook 2003: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2003), pp. 659–66. The threshold for allowable lethality when NLWs are used properly is generally

Research on NLWs has been prompted partly by the 2002 incident at the Dubrovka Theatrical Centre in Moscow during which at least 125 hostages were killed by an opioid that was used by Russian special forces to put Chechen hostage takers to sleep.[12] The post-cold war international security environment not only increasingly emphasizes the potential threats posed by non-state actors (i.e. terrorists), but also the desire to limit the use of lethal force during international peacekeeping and counterterrorism or counter-insurgency operations. The blurring of the distinction between domestic and international conflicts complicates such considerations: police forces may take on military functions, while military forces may be tasked to carry out peacekeeping or peacebuilding operations.[13]

So-called operations other than war involve peacekeeping, peace support and humanitarian initiatives, and the use-of-force constraints in such situations require that special effort be made to ensure that collateral casualties be held to a minimum. NLWs are now considered for the full spectrum of conflict from major theatre wars to small-scale contingencies, fighting piracy, peacetime operations and homeland defence.[14] Some 12 candidate technologies have been identified by potential application and delivery modes and grouped into six categories: (*a*) kinetic energy technologies, (*b*) chemical and materiel technologies, (*c*) directed energy technologies, (*d*) acoustic technologies, (*e*) electrical technologies, and (*f*) barriers and entanglements. This Policy Paper focuses on chemical and materiel technologies.

NLWs function in three areas to achieve counter-personnel, -materiel, and -capability objectives (i.e. incapacitating people and equipment, and disabling or neutralizing facilities and systems). NLW technologies include: (*a*) acoustic systems; (*b*) chemicals, including malodorants and riot control, anti-traction and lubricating agents; (*c*) communication systems; (*d*) information technologies; (*e*) optical devices; (*f*) munitions; and (*g*) non-penetrating projectiles.

Terminology also complicates the consideration of NLW issues. Chemical- or biological-based substances may be referred to as bio-regulators, incapacitants, irritants, less-than-lethal weapons and RCAs. Robert Bunker has provided a

not greater than 3%. This figure is not necessarily acceptable in operations where civilians may be affected during 'operations other than war'.

[12] Hart, Kuhlau and Simon (note 11), pp. 659–66. In a 2007 interview on the fifth anniversary of the incident, 3 of the hostages discussed their experiences and the political consequences of the siege. Radio Ekho (Moscow), [Nord-Ost: 5 years], 21 Oct. 2007, <http://www.ncjrs.gov/pdffiles1/nij/sl000810.pdf> (in Russian). See also Dunlop, J. B., *The 2002 Dubrovka and 2004 Beslan Hostage Crises: a Critique of Russian Counter-Terrorism*, Soviet and Post-Soviet Politics and Society series (*ibidem*–Verlag: Stuttgart, 2006).

[13] Findlay, T., SIPRI, *The Use of Force in Peace Operations* (Oxford University Press: Oxford, 2002); and Daniel, D. C. F., Taft, P. and Wiharta, S. (eds), *Peace Operations: Trends, Progress, and Prospects* (Georgetown University Press: Washington, DC, 2008).

[14] US Department of Defense (DOD), *Defense Planning Guidance* (DOD: Washington, DC, 2001).

major review of terms and references on NLWs,[15] and a bibliography of NLW information that covers the Internet, books, documents and periodicals.[16] Important analyses on NLWs have also been provided by the Bradford Non-Lethal Weapons Research Project at Bradford University,[17] and the Council on Foreign Relations.[18]

Legal considerations

Complex legal arguments have been developed to support interpretations for restricting, prohibiting or permitting research into and use of NLWs. For example, within the context of the CWC there has been debate about whether 'domestic riot control' is a subset of 'law enforcement' and, if so, whether this should restrict the types of NLWs that may be developed to those meant for domestic riot control purposes only (see table 2.1). Other analyses emphasize the importance of considering multiple legal regimes, including international humanitarian law.[19] It is agreed that the CWC does not prohibit the use of toxic chemicals for judicial executions. Therefore, toxicity per se cannot be used as the determining factor when deciding whether it is permissible to develop chemicals for use as NLWs or incapacitants. However, it has been argued that toxicity should be assessed in terms of the object and purpose of the CWC. Those who make this argument refer to phrasing in the CWC's definition of a chemical weapon which states that 'types and quantities' of toxic chemicals and their precursors must be 'consistent' with purposes not prohibited by the CWC. Whether and how to place limits on the toxicity of chemicals that are developed in future for RCA purposes have also been discussed.

The BTWC prohibits the 'development, production, stockpiling or acquisition of biological agents or toxins' other than for peaceful purposes. The CWC prohibits the development, production, acquisition, transfer, stockpiling and use of chemical weapons (and, in principle, any toxin).[20] Its definition of a chemical

[15] Bunker, R. J., *Non-Lethal Weapons: Terms and References*, US Air Force (USAF) Institute for National Security Studies (INSS) Occasional Paper no. 15 (USAF INSS: Air Force Academy, Colo., 1996), <http://www.angelfire.com/or/mctrl/nonlethal.html>.

[16] Kiss, T., 'Non-lethal weapons', Maxwell Air Force Base (AFB), AL, July 2005, <http://www.au.af.mil/au/aul/bibs/soft/nonlethal.htm>.

[17] See the Bradford Non-Lethal Weapons Research Project website, <http://www.brad.ac.uk/acad/nlw/>; and Davison, N. and Lewer, N., Bradford Non-Lethal Weapons Research Project Research Report no. 8, Mar. 2006, <http://www.bradford.ac.uk/acad/nlw/research_reports/>.

[18] Allison, G. T., Kelley, P. X. and Garvin, R. L., *Non-Lethal Weapons and Capabilities* (Council on Foreign Relations: Washington, DC, Feb. 2004). See also Council on Foreign Relations, 'Nonlethal weapons', <http://www.cfr.org/issue/61/nonlethal_weapons.html>.

[19] E.g. Krutzsch, W., '"Law enforcement including domestic riot control": the intent of the CWC negotiators', 18 Feb. 2007, Paper presented at the 52nd Pugwash CBW Workshop '10 Years of the OPCW: Taking Stock and Looking Forward', Noordwijk, Netherlands, 17–18 Mar. 2007, <http://www.pugwash.org/reports/cbw/52nd-workshop-2007/1-Krutzsch.pdf>.

[20] CWC (note 4), Article I.

Table 2.1. Principal provisions of the 1993 Chemical Weapons Convention regarding chemicals that may be used for domestic riot control or for other law enforcement purposes

Relevant provision	'Domestic riot control'	Other 'law enforcement' purposes
Types and quantities must be consistent with such purposes	Article II, paragraph 1(a)	Article II, paragraph 1(a)
Must not be used or intended as a 'method of warfare' (i.e. where the toxic properties of the chemical are used to cause harm)	Article II, paragraph 9(c)	Article II, paragraph 9(c)
Must not be in Schedule 1		Verification Annex, Part VI, paragraph 2
'Any chemical not listed in a schedule which can produce rapidly in humans irritation or disabling physical effects which disappear within a short time following termination of exposure'	Article II, paragraph 7	For law enforcement chemicals other than 'riot control agents' there is no such specification of properties
Chemical name and structural formula must be declared	Article III, paragraph 1(e)	No declaration requirement

Source: '"Law enforcement" and the CWC', *CBW Conventions Bulletin*, no. 58 (Dec. 2002), p. 2.

weapon is critical since the definition can be interpreted as allowing the use of some NLWs.[21] The prohibitions of both conventions contain phrasing known as the 'general purpose criterion'. This essentially prohibits all biological substances and toxic chemicals and their precursors except for non-prohibited purposes. This is the mechanism by which future technological and scientific developments may be judged to ensure that the prohibitions are not undermined. The CWC prohibits the use of a weapon that relies on its toxic effect as a 'method of warfare'. Article III of the CWC requires a party to provide the chemical name, structural formula and Chemical Abstracts Service number for all chemicals that it holds for riot control purposes. Under Article X (Assistance and protection

[21] CWC (note 4), Article II.

against chemical weapons) a party can state whether it believes that RCAs have been used against it as a 'method of warfare'.[22]

Any agreement may be implemented 'narrowly' according to the letter or, more broadly, according to the 'spirit' of the agreement. Those who emphasize the importance of not undermining the object and purpose of the CWC, for example, tend to warn against interpreting agreements too narrowly. This difference is also reflected in discussions on whether the intent of the negotiators of the CWC matters: should that intent be taken into account or should the CWC's provisions be understood solely within the context of those provisions?

Furthermore, there is no consensus on the significance of linkages between various legal regimes, and there is also a gap between the various legal analyses and how they can be placed into practice. Finely crafted legal and political arguments may seem so complicated that policymakers may be unable to envisage desired outcomes or conceive a politically acceptable route to implementing decisions.

Technical feasibility and safety concerns

The technical feasibility of achieving effective and 'safe' dosages of an agent is also much debated. Some chemical warfare agents may be considered less-than-lethal. For example, adamsite has been stockpiled for use as both a chemical warfare agent and as an RCA, yet it is generally considered to be ineffective as a chemical warfare agent and too dangerous for riot control purposes.

In addition, lethality and safety consideration standards have traditionally been developed by state military programmes for use in state-based conflicts. Such standards are not necessarily appropriate for application in a civilian or domestic environment. Lynn Klotz, Martin Furmanski and Mark Wheelis have suggested that no chemical (or biochemical) compound possesses the necessary characteristics for it be considered 'non-lethal'.[23] They and others observe, for example, that there is currently little evidence in medical circles of the existence of a chemical that can have a high therapeutic index. The therapeutic index (LD_{50}/ED_{50}) is the ratio of the amount of a therapeutic agent which causes a desired therapeutic effect (ED_{50}) and the amount which causes toxic effects (LD_{50}).[24] Typical sedatives have an index of 5–10 and are administered to humans under medical supervision.[25]

[22] CWC (note 4), Article X, para. 8(b).

[23] Klotz, L., Furmanski, M. and Wheelis, M., *Beware the Siren's Song: Why 'Non-lethal' Incapacitating Agents Are Lethal* (Federation of American Scientists: Washington, DC, 2003), <http://www.fas.org/bwc/papers/sirens_song.pdf>.

[24] LD_{50} is the dose that kills 50% of animals tested (LD = lethal dose). ED_{50} is the amount of a drug that is therapeutic for 50% of the people to whom it is administered (ED = effective dose).

[25] Organisation for the Prohibition of Chemical Weapons, 'Switzerland: riot control agents and incapacitating agents under the Chemical Weapons Convention', document RC-2/NAT.12, 9 Apr. 2008.

A less-than-lethal chemical warfare agent should possess additional characteristics. Such an agent should: (*a*) be highly potent—as evidenced by the rapidity of the effect, its duration, the degree of incapacitation and the reliability of the effect; (*b*) have a high safety margin; (*c*) have an effect that can be reversed by an available antidote; (*d*) be able to be 'weaponized'—easily readied (e.g. the dosage needed should be readily calculated), readily dispersible as an aerosol and easily administered; and (*e*) be odourless and tasteless.[26]

A 2007 joint technical report by the CWC's Organisation for the Prohibition of Chemical Weapons (OPCW) and the International Union for Pure and Applied Chemistry concludes that:

> a clear need exists for States Parties to the CWC to address these risks to the object and purpose of the CWC and to agree on the CWC compatibility (or incompatibility) of endeavors to develop and field 'nonlethal' weapons that utilize toxic (e.g., incapacitating) chemicals for law enforcement purposes. Should the development and acquisition of such weapons be accepted, there would clearly be a need (as is the case of riot control agents) to agree on declaration provisions for such weapons (types, quantities, and delivery systems).[27]

The OPCW could further consider the implications of NLWs for the CWC and the practicality of agreeing specific measures to address the underlying concern and uncertainty about such agents. For example, Switzerland tabled a paper during the Second CWC Review Conference in April 2008 that emphasized the importance for the regime of better addressing NLWs and contained the following proposals.

1. Any 'toxic chemical' is by definition a chemical weapon except where it is intended for non-prohibited purposes and 'acquired in appropriate types and quantities'.
2. Riot control agents and incapacitating agents are 'toxic chemicals' as defined by the CWC and, therefore, they are chemical weapons unless they are intended for purposes not prohibited by the CWC.
3. Incapacitating agents are 'toxic chemicals' whose action on life processes differs from that of RCAs because they act on the central nervous system.
4. 'Toxic chemicals' may be used for law enforcement other than for riot control by 'governmental authorities'.
5. In the context of the CWC, 'law enforcement' is not necessarily limited to domestic law enforcement. The circumstances in which law enforcement, including the use of RCAs, may occur outside a state's own territory must be 'carefully weighed'.
6. The use of RCAs for 'law enforcement' by armed military personnel may be in accordance with the object and purpose of the CWC in the context of 'peace

[26] Organisation for the Prohibition of Chemical Weapons (note 25).

[27] Balali-Mood, M. et al., 'Impact of scientific developments on the Chemical Weapons Convention (IUPAC Technical Report)', *Pure and Applied Chemistry*, vol. 80, no. 1 (2008), p. 186, para. 18.

operations' which 'are considered legitimate under international law'. However, RCAs may not be used against 'combatants'.

7. The development of incapacitants and 'certain related means of delivery' has parallels to the development of new 'chemical weapons' and could undermine the object and purpose of the CWC.

8. The use of incapacitating agents by 'military personnel in an international context is not admissible'. In view of the potentially severe physiological effects, and the possibility that toxic chemicals may be used in retaliation, 'it cannot be brought in line with the object and purpose' of the CWC.

9. Incapacitating agents are 'toxic chemicals' and their application is 'comparable' to RCAs, although their effects are more severe. This warrants measures that are 'comparable to those which are in force' for RCAs.[28] (The European Union has also urged that all parties to the CWC should declare their RCA holdings.[29])

The Second CWC Review Conference was unable to agree whether to include the word 'incapacitant' (or an equivalent term) in its final document. However, some participants supported including scientific developments for the production of 'chemicals that can cause death, temporary incapacitation or permanent harm to humans or animals' and their possible impact on the CWC in the document.[30] The Second CWC Review Conference did, however, reaffirm the understanding of the parties that RCAs may not be used as a method of warfare.[31]

Types of non-lethal weapons

A large number of chemicals have been suggested for use as NLWs; they can be classified as anti-personnel and anti-materiel chemicals. Anti-personnel chemicals are intended to prevent people as individuals or in crowds from taking certain actions (i.e. to inhibit or incapacitate them, but only temporarily and with no lasting side effects). Anti-materiel weapons disable vehicles and prevent the operation of electronics and so hinder infrastructure function.

Anti-materiel compounds include combustion modifiers, fuel contaminants, lubricant contaminants and other agents which disable engines and vehicles. Corrosives, abrasives and depolymerization agents can be used against various types of infrastructure.

[28] Organisation for the Prohibition of Chemical Weapons (note 25).

[29] Council Common Position 2007/469/CFSP of 28 June 2007, relating to the 2008 Review Conference of the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (CWC), *Official Journal of the European Union*, L176 (6 July 2007), p. 40, article I(b)(i).

[30] CWC (note 4), Article II, para. 2.

[31] Organisation for the Prohibition of Chemical Weapons, 'Report of the Second Special Session of the Conference of the States Parties to review the operation of the Chemical Weapons Convention (Second Review Conference), 7–18 April 2008', document RC-2/4, 18 Apr. 2008, p. 5, para. 9.2.

Anti-personnel agents encompass RCAs, malodorants, and calmatives. RCAs include chemicals that irritate mucous membranes, cause lacrimation, irritation and inflammation. They produce rapid irritation and effects which may disappear rapidly. The best known are Chloroacetophenone (CN) and ortho-Chlorobenzylidene malononitrile (CS), commonly referred to as tear gas. Oleoresin capsicum (OC), which is the active ingredient in hot peppers, has replaced CS and is widely used by police agencies; its effectiveness and suitability are the subject of disagreement because of their suspected role in in-custody deaths.[32]

The Edgewood Chemical and Biological Center has extensively examined malodorants to obtain materials with repulsive odours. Some are natural odours while others are synthetics. Mixtures of malodorants and irritants are often used. However, sensitivity decreases with exposure and their effectiveness as agents also diminishes with exposure.

Calmatives are of great interest as NLWs.[33] High concentrations of calmatives lead to unconsciousness or death, but it is believed that they can be safely yet effectively used and are thus candidates as possible NLWs. Calmatives produce rapid onset of symptoms—one minute when inhaled and three to five minutes when absorbed through the skin for the fentanyls that have been investigated by the US military. Safe use of calmatives would necessitate a delivery system that limits exposure to below the levels that lead to death or cause serious harm.[34]

Activities and programmes

The US Joint Non-Lethal Weapons Directorate was established in 1996, under the US Marine Corps.[35] Between 1997 and 2003 it had an annual budget of $22 million; in 2004 this was increased to $43 million. Although exact figures are not readily available, the proposed investment plan since 2004 suggests that expenditure on NLWs could double for the period 2008–13.[36] This increase in funding reflects the US military's aim to accelerate the development of NLWs. Some analysts regard this programme with concern partly because it is unclear how the 'non-lethality' criteria would be applied in practice.[37]

Although most available information is on the activities of the US military, many military organizations follow NLW issues, including their possible adop-

[32] Jones, T. L., *Specialty Police Munitions* (Paladin Press: Boulder, CO, 2000).

[33] Lakoski J. M., Murray, W. B. and Kenny, J. M., 'The advantages and limitations of calmatives for use as a non-lethal technique', Pennsylvania State University, College of Medicine, Applied Research Laboratory, Oct. 2000, available at <http://www.sunshine-project.org/incapacitants/jnlwdpdf/psucalm.pdf>.

[34] Klotz, Furmanski and Wheelis (note 23), p. 6. The Joint Non-Lethal Weapons Directorate defines a non-lethal chemical weapon as one that incapacitates 98% of the target population while causing fewer than 0.5% fatalities.

[35] US Department of Defense (note 3).

[36] Sherman, J., 'DoD: spend more on non-lethal weapons', 24 May 2006, Military.com, <http://www.military.com/features/0,15240,98297,00.html>.

[37] 'The future of crowd control', *Science and Technology Quarterly*, Economist.com, 3 Feb. 2005.

tion and use, with interest. The United Kingdom has carried out several joint war-gaming operations to evaluate the effectiveness of NLWs in military operations on urban terrain, and several symposiums on NLWs have also been held in Germany.[38] The organizing committee members for the symposiums include most European states and Russia. In addition, the International Law Enforcement Forum is creating an NLW database in order to provide online access to original-source information on such weapons and related technologies to registered government, military, law enforcement and research agencies.[39] The database will be made publicly available when completed.

[38] The programmes of these events are available at European Working Group Non-Lethal Weapons, 'Non-lethal weapons', <http://www.non-lethal-weapons.com/>.

[39] International Law Enforcement Forum, 'Less lethal weapons database', <http://www.ilef.org/>.

3. Chemical agents

Essentially non-lethal chemical agents can be classed as riot control agents, incapacitants, calmatives and malodorants. 'Riot control agents' is a general term that can also be understood to encompass all such agents. Some, such as CS, are 'traditional' or 'standard', while others, such as various malodorants, have never had wide application. It is important to consider both the physiological effects of such agents and guidelines for when and how to use them (e.g in situations that do not involve 'riot control').

Riot control agents[40]

A riot control agent is designed to temporarily disable by causing intense irritation of the mucous membranes, eyes and skin. Its toxic effects should be limited to the areas where sensory irritation has occurred. RCAs are intended to be safe when used according to the manufacturer's specifications, but their potential widespread use raises concerns about possible health and safety problems. There should be a large margin between the dosage of an RCA that is effective and the dosage that produces adverse effects. High-level exposure can cause ocular, pulmonary and dermal injuries and the use of RCAs in enclosed spaces can produce toxic effects. There is a need for additional research to establish the biological and toxicological effects of RCAs, and this is especially true of the use of RCAs in law enforcement activities where they are often misused deliberately or through ignorance.

RCAs have three common characteristics: rapid onset of effect, brief duration of effect, and high safety ratio (i.e. ratio of lethal dose, LD, to effective dose, ED). There are three types of RCAs: lachrymators, sternutators and vomiting agents (see table 3.1). The major agents used as RCAs are CS, CN and diphenylaminearsine (DM). Other common RCA agents include dibenz[b,f][1,4]oxazepine (CR), bromobenzylcyanide (CA), trichloronitromethane (chloropicrin, PS) and bromoacetone (BA).

All RCAs affect people in the same way. Irritation or burning in the eye progresses to pain followed by blepharospasm, lacrimation and conjunctival injection. This causes the eye to close. The mucous membranes of the mouth feel discomfort, burning and salivation, which is accompanied by pain inside the nose.

[40] Compton, J. A. F., *Military Chemical and Biological Agents* (Telford Press: Caldwell, N.J., 1987), pp. 191–252; Sidell, F. R., Takafuji, E. T. and Franz, D. R. (eds), *Textbook of Military Medicine: Medical Aspects of Chemical and Biological Warfare* (Borden Institute, Walter Reed Army Medical Center: Washington, DC, 1997), pp. 307–24; Virtual Naval Hospital, <http://www.vnh.org/>; Olajos, E. J. and Salem, H., 'Riot control agents: pharmacology, toxicology, biochemistry and chemistry', *Journal of Applied Toxicology*, vol. 5 (2001), pp. 355–91; and Olajos, E. J. and Stoppford, W. (eds), *Riot Control Agents: Issues in Toxicology, Safety, and Health* (CRC Press: Boca Raton, FL, 2004).

There is tightness in the chest, coughing and sneezing. Unprotected skin is affected by tingling or burning, with erythema developing at exposed sites. The principal physiological effects of RCAs are shown in table 3.2. They appear rapidly but usually dissipate quickly, although they can persist for up to an hour.

Irritants have been used by the military for centuries, but a scientific understanding of their use was developed during World War I. Ethyl bromoacetate, a lachrymator, was initially used by France, and Germany introduced lethal gases in 1915 with its use of chlorine. About 30 substances were used in World War I for their supposed irritant activity but many did not function well. The use of riot control agents in war was pioneered by the USA in Viet Nam. In 1968 France used RCAs for crowd control in Paris, and the United Kingdom developed RCAs for use in crowd control in Northern Ireland in the 1960s. Law enforcement agencies worldwide continue to hold RCAs.

One RCA that is frequently used for crowd control is CN, also known as Mace. However, CS is the compound that is probably most used by military and law enforcement officials.

CS

CS was synthesized by Ben Corson and Roger Stoughton in 1928, and it replaced CN as the standard US riot control agent in 1969.[41] CS was adopted for law enforcement purposes in the 1950s because it is more effective than CN since it can be dispersed by solution spraying, explosive dispersion or as smoke from a pyrotechnic mixture. It is flammable, and decontamination is difficult because of its low solubility in water.

Individuals can develop a tolerance to CS, especially if they are exposed to it regularly. The usual route for absorption is by respiration. CS is also a skin irritant and dermatitis may develop; if the temperature and humidity are high the effects of exposure to CS may be more severe.

The eye is strongly affected by RCAs; if CS is sprayed into the eyes, they cannot be opened for some time and corneal oedema can occur for 2–6 hours following exposure.[42] There are few instances of CS ingestion. The oral dose that kills 50 per cent of the animals tested (LD_{50}) for rabbits is 212 milligrams of CS per kilogram. No human deaths from ingestion of CS have apparently occurred. Metabolically, CS is hydrolysed to chlorobenzaldehyde and malanonitrile, which eventually forms thiocyanide.

[41] Corson, B. B. and Stoughton, R. W., 'Reactions of alpha, beta-unsaturated nitriles', *Journal of the American Chemical Society*, vol. 50 (1928), pp. 2825–36; and Jones, G. R. N., 'CS and its chemical relatives', *Nature*, 4 Feb. 1972, pp. 257–61.

[42] Leikin, J. B. and McFee, R. B. (eds), *Handbook of Nuclear, Biological and Chemical Agent Exposures* (CRC Press: Boca Raton, FL, 2007), p. 352.

Table 3.1. Riot control agents

Agent	Designation(s)	Chemical formula(ae)	Chemical Abstracts Service number
Ortho-Chlorobenzylidene malononitrile	CS	$C_{10}H_6ClN_2$	2698-41-1
Chloroacetophenone	CN	C_8H_7ClO	532-27-4
Diphenylaminearsine, adamsite	DM	$C_6H_4(AsCl(NH)C_6H_4$, $C_{12}H_9AsClN$	578-94-9
Dibenz[b,f][1,4]oxazepine	CR	$C_{13}H_9NO$	257-07-8
Bromobenzylcyanide	CA	C_8H_6BrN	5798-79-8
Chloropicrin	PS	CCl_3NO_2	76-06-2
Bromoacetone	BA	C_3H_6BrO	598-31-2

CN

CN was first synthesized in 1871 by Carl von Graebe, and it was used in World War I.[43] It is a solid and can be disseminated as smoke. It is also available in powder and liquid formulations and is sold as Mace for self protection. It can be mixed with capsaicin for use as pepper spray. The clinical effects of CN are similar to those of CS, but it is more toxic and more likely to cause serious side effects. The harassing concentration of CN is two and a half times that of CS,[44] and laboratory studies rate its effects as equivalent to those of CS but threefold to tenfold more toxic. CN is a more potent skin irritant than CS and its use can lead to allergic responses, especially if the skin is exposed. Eye injuries can also be more extensive with CN than with CS. Both CS and CN can cause severe complications, especially if they are used in confined spaces, such as in prison incidents.

DM

DM, also known as adamsite, is a member of the 'vomiting agents'. It was synthesized by more than one research group during World War I and is named for Roger Adams, who perfected its synthesis in 1918. It is not volatile and is insoluble in water, as are most organic solvents. The threshold for irritation is low. DM primarily affects the upper respiratory tract by causing irritation of nasal and sinus mucosae, burning in the throat and tightness of the chest. Uncontrollable coughing and sneezing with eye irritation also occur. DM is more toxic than other RCAs. The effects of exposure to DM do not appear immediately

[43] von Graebe, C., *Berichte der Deutschen Chemischen Gesellschaft*, vol. 4 (1871), pp. 34–35.

[44] A harassing concentration of a chemical agent is one which requires masking or other protective measures. Such concentrations may be insufficient to kill, but sufficient to interfere with normal operations. 'Lesson 1. Fundamental aspects of chemical agents', Globalsecurity.org, <http://www.globalsecurity.org/military/library/policy/army/accp/cm3404/le1.htm>.

but the agent will cause a soldier to remove his or her mask. There may be prolonged systemic effects, such as headache, chills, nausea, cramps, vomiting and diarrhoea. Several deaths following exposure to DM have been reported.

CR

CR was first synthesized in 1962 and is more potent but less toxic than CS. It is dispersed in solution (i.e. as a liquid). It does not degrade in water and thus persists in the environment. Its effects are similar to those of CS but it is about five times more potent. Limited data are available on CR but it appears to be much safer than CS because it seems to have little effect on the lower airways or lungs. There do not appear to be persistent skin or eye effects.

CA

CA was introduced in World War I and it is the most potent riot control agent. It is not stable and is corrosive. It causes lacrimation of the eyes at low concentrations. The effects on health are similar to those associated with exposure to CS and CN, yet it is relatively unimportant as a riot control agent.

PS

Chloropicrin was used extensively as a lachrymator, choking and vomiting agent by France, Germany, Russia and the UK during World War I. Soldiers have been exposed to chloropicrin for training purposes, and it has also been used to control pests. It cannot be used as an RCA under the provisions of the CWC because it is listed in the convention's Annex on Chemicals.[45]

BA

Bromoacetone is prepared by reacting bromine and acetone (a common solvent). It was employed during World War I as a lachrymator.

Summary

RCAs may be safe if used as intended, but a significant number of casualties may result when they are used indiscriminately. Such problems may be caused either by the delivery system or the solvent employed. CS appears to be the most benign of the riot control agents. More research is needed to investigate the effect on health of exposure to RCAs, especially when used by law enforcement agencies.

There are numerous criticisms of the use of riot control agents.[46] Howard Hu and his co-authors state that: 'the use of tear gas in situations of civil unrest,

[45] CWC (note 4), Article II, para. 7.

[46] Hu, H. et al., 'Tear gas: harassing agent or toxic chemical weapon', *Journal of the American Medical Association*, vol. 262, no. 5 (4 Aug. 1989); Fraunfelder, F. T., 'Is CS gas dangerous?', *British Medical Journal*,

Table 3.2. Principal physiological effects of riot control agents

Area affected	Physiological effects
Airway	Coughing, irritation, sneezing, tightness in the chest, secretions
Eye	Blepharospasm, burning and irritation, tearing, photophobia
Gastrointestinal tract	Gagging, retching, vomiting
Mouth	Burning sensation of mucous membranes, salivation
Nose	Burning sensation, rhinorrhea
Skin	Burning sensation, erythema

Source: Adapted from Sidell, F. R., Takafuji, E. T. and Franz, D. R. (eds), *Textbook of Military Medicine: Medical Aspects of Chemical and Biological Warfare* (Borden Institute, Walter Reed Army Medical Center: Washington, DC, 1997), p. 311.

however, demonstrates that exposure to the weapon is difficult to control and indiscriminate and the weapon is often not used correctly' and 'published and unpublished in vitro tests have shown ortho-chlorobenzylidene malononitrile to be both clastogenic and matogenic'. They also state that there is a need for an investigation of the full toxicological potential of tear gas chemicals. Another author notes that: 'In Britain, there has been persistent concern about the use of CS gas'.[47]

Incapacitating agents[48]

An incapacitant is a chemical agent which produces a temporary disabling condition that persists for hours to days after exposure to the agent has occurred (unlike the short-term effects of RCAs). The term denotes substances that temporarily impair performance by targeting the central nervous system. Anticholinergic agents appear to be most suited for military use.

Medical treatment following exposure to an incapacitant may not be necessary but may facilitate recovery. This means that such agents: (*a*) are highly potent; (*b*) alter the regulatory activity of the central nervous system; (*c*) have a duration

vol. 320 (19 Feb. 2000), pp. 458–59; and Blaho, K. et al., 'Is CS spray dangerous?', *British Medical Journal*, vol. 321 (1 July 2000), p. 46.

[47] Fraunfelder (note 46).

[48] Compton (note 40), pp. 253–34; Ketchum, J. S. and Sidell, F. R., 'Incapacitating agents', eds Sidell, Takafuji and Franz (note 40), pp. 287–305; Federation of American Scientists, Working Group on Biological and Chemical Weapons, 'Position paper: the threat of chemical incapacitating agents', Mar. 2003, <http://www.fas.org/bwc/nonlethal.htm>; Dando, M. R., 'The danger to the Chemical Weapons Convention from incapacitating chemicals', First CWC Review Conference Paper no. 4, University of Bradford, Department of Peace Studies, Mar. 2003; Fidler, D., 'Incapacitating chemical and biochemical weapons and law enforcement under the Chemical Weapons Convention', and Furmanski, M., 'Military interest in low-lethality biochemical agents: the historical interaction of advocates, experts, pragmatists and politicians', Background papers prepared for the Symposium on Incapacitating Biochemical Weapons: Scientific, Military Legal and Policy Perspectives and Prospects, Geneva, 11 June 2005.

of action lasting from hours to days; (*d*) are not dangerous to life except at many times the effective dose; and (*e*) are not likely to produce permanent injury. These criteria eliminate many drugs, such as various opiates and sedatives, from use as incapacitants.

Chemical and biological incapacitating agents can be categorized according to their principal physiological effects as: olfactory assault agents, vesicants, irritants or nausea-producing agents, psycho-chemical agents (substances whose most prominent effects are psychological or behavioural), stimulants, depressants, psychedelics and deliriants.[49] Such agents pass the blood–brain barrier and affect the central nervous system (i.e. they interfere with higher brain functions). They are easily counteracted and, in theory, disable behaviour at a lower dosage than that which would produce lethal effects.

Stimulants include amphetamines, caffeine, cocaine and nicotine. None is potent enough to be used as an incapacitating agent. Depressants, such as barbituates, appear to be potentially more useful as incapacitants. Opioids are potential incapacitants but are usually too potent to be used. Psychedelics such as D-lysergic acid diethylamide (LSD) were of great interest to the US military and were tested for use in 1959–65, but the tests showed that the results of their use were too unpredictable. Phenethylamine is a substance that is believed to act as a neuromodulator or neurotransmitter. If food containing phenethylamine is consumed in sufficient quantities, it may result in psychoactive effects. Anticholinergics block the effects of acetylcholine in either the peripheral or the central nervous systems. The best known anticholinergics are atropine and scopolamine. Scopolamine is about seven times more potent than atropine: about 2 mg of scopolamine will incapacitate a soldier, while 10–12 mg of atropine would be required to produce the same effect, which would last 4–8 hours.

Leo Sternbach and a colleague noted that 5 of 17 esters showed 'antiacetylcholine activity equaling or surpassing that of atropine' (of 7 basic bicyclic alcohols prepared).[50] Atropine and various oximes stimulate the enzyme acetylcholinesterase (the enzyme inhibited by organophosphorus nerve agents) and thus afford a degree of symptomatic relief. At the time their research was carried out military scientists were working on V-agents (a category of organophosphorus nerve agents) and their findings were greeted with enthusiasm at the British and US military research facilities where there was interest in an atropine-type antidote.

Research on antispasmodic bicyclic alcohols led to the development of a series of non-barbituate tranquilizers and antispasmodics. They had the intoxicating effects of atropine and other effects similar to those of many known substances

[49] Psycho-chemicals, in turn, can be divided into stimulants, depressants, psychedelics and deliriants. Ketchum and Sidell (note 48), pp. 291–94.

[50] Sternbach, L. H. and Kaiser, S., 'Antispasmodics II: esters of basic bicyclic alcohols', *Journal of the American Chemical Society*, vol. 74, no. 9 (5 May 1952), pp. 2219–21.

that affect the central nervous system. They were not atropine substitutes but had effects similar to those of RCAs and could be vapourized thermally.

These studies also led to the synthesis and weaponization of 3-Quinuclidinyl benzylate (BZ) as part of the beginning of work on psychedelic warfare agents.[51] BZ blocks the action of acetylcholine on both the peripheral and central nervous systems. It stimulates the action of noradrenaline in the brain in a manner similar to the effect of amphetamines and cocaine. BZ also induces hallucinations and sedates those exposed to it. Delirium is common. BZ was weaponized at Pine Bluff Arsenal in Arkansas between 1962 and 1964, but it was eventually removed from the US arsenal of chemical weapons because of its unpredictable effects on combat troops.

LSD is an extremely powerful hallucinatory substance that was investigated for use as an incapacitant. It was deemed too potent for use as a central nervous system stimulant and was eliminated as a battlefield agent, particularly due to the possibility of downwind contamination of support elements (e.g. food, medical and logistical supplies). It could therefore probably only be used against an opponent's supply lines and staging areas.

Other compounds that were studied for possible use as incapacitants included cocaine, amphetamine, dexamphetamine, methamphetamine, mescaline, psilocybin and phenylcyclidine (PCP).

Incapacitants that interfere with the ability of military personnel to carry out their duties were investigated, but the many uncertainties associated with their use led the major military powers to eliminate them from consideration. However, the varying roles played by the military have kept interest in incapacitants alive. A BZ derivative or a potent glycolate are possible candidates for use as incapacitants. (Glycolates are a class of compounds that act as anticholinergic agents, that is, they block the neurotransmitter acetylcholine.) The use of LSD, psychedelic phenylethylamines or opioids remains possible but their weaponization for use as chemical warfare agents appears unlikely. The possible use of modern pharmaceutical developments to create incapacitants has been discussed, and Malcolm Dando has examined the implications for the CWC of such an approach.[52]

Calmatives[53]

The term 'calmative agents' (a military, not a scientific term) covers psychoactive substances that produce effects ranging from unconsciousness to hallucinations.

[51] Ketchum, J. S., *Chemical Warfare Secrets Almost Forgotten: A Personal Story of Medical Testing of Army Volunteers with Incapacitating Chemical Agents during the Cold War (1955–1975)* (James S. Ketchum: Tehachapi, CA, 2006).

[52] Dando (note 48).

[53] Sunshine Project, 'Non-lethal weapons research in the US: calmatives and malodorants', Backgrounder series, no. 8, July 2001, <http://www.hartford-hwp.com/archives/27a/120.html>; Stone, A., 'US

The so-called safe range (between unconsciousness and death) for the use of such agents is small because it is difficult to calculate the effect of their use unless the health and age of the target group is known. The use of calmatives by the military increases their acceptance and makes law enforcement officials more likely to use them.

In 1992 the US Army's Advanced Riot Control Agent Device (ARCAD) programme was terminated because of the success of the negotiations on the Chemical Weapons Convention. With the advent of the CWC, ARCAD was no longer deemed necessary. However, when the US Joint Non-Lethal Weapons Directorate was established in 1996, some of ARCAD's activities were transferred to it, particularly those related to calmatives and malodorants. Research thus continued into the chemical effects of calmatives and malodorants and the effects of anti-materiel NLWs (see chapter 2).

In order to determine the advantages and limitations of the use of calmatives as NLWs, Pennsylvania State University studied selected calmatives, including benzodiazapines, alpha adrenergic receptor agonists,[54] dopamine D3 receptor agonists, selective seratonin reuptake, opioid receptors and Mu agonists, neurolept anaesthetics, corticotropin-releasing factor receptor antagonists, receptor antagonists and cholecystokinin B receptor antagonists.[55] The study also noted that promising breakthroughs had been made in improved drug delivery of macromolecular compounds of interest in this context. Specific drugs, such as diazepam and dexmedetomidine, were listed as appropriate for use as NLWs.

The Russian opioid controversy[56]

On 23 October 2002, about 50 Chechen terrorists stormed the Dubrovka Theatrical Centre in Moscow and took approximately 800 hostages.[57] The terrorists were

research on sedatives in combat sets off alarms', *Science*, 2 Aug. 2002; Sunshine Project, 'US military operating a secret chemical weapons program', News release, 24 Sep. 2002; Sunshine Project, 'Pentagon program promotes psychpharmacological warfare', News release, 2 July 2002, <http://www.freerepublic.com/focus/news/711950/posts>; Sunshine Project, 'The return of ARCAD', News release, 6 Jan. 2004; and Sunshine Project, 'US/UK non-lethal weapons (NLW)/urban operations executive seminar', London, Assessment report, 30 Nov. 2000.

[54] An agonist is a drug that binds to a receptor and triggers a response by a cell, often mimicking a naturally occurring substance. An antagonist has the opposite effect and blocks a reaction.

[55] Lakoski, Murray and Kenny (note 33).

[56] Wheeler, J., 'The secret Russian gas identified', Freedom Research Foundation, 28 Oct. 2002, <http://www.newsmax.com/archives/articles/2002/10/28/160126.shtml>; Miller, J. and Broad, W. J., 'Hostage drama in Moscow: the toxic agent—US suspects opiate in gas in Russia raid', *New York Times*, 29 Oct. 2002; Ruppe, D., 'CWC: experts differ on whether Russian hostage rescue violated treaty', Nuclear Threat Initiative, 30 Oct. 2002, http://www.nti.org/d_newswire/issues/newswires/2002_10_30.html#11>; Ember, L., 'Opiate ends hostage crisis', *Chemical & Engineering News*, 4 Nov. 2002; MacKenzie, D., 'Mystery of Russian gas deepens', *New Scientist*, 29 Oct 2002; and James Martin Center for Nonproliferation Studies, Chemical and Biological Weapons Nonproliferation Program, 'The Moscow theatre hostage crisis: incapacitants and chemical warfare', 4 Nov. 2002, <http://cns.miis.edu/pubs/week/02110b.htm>.

[57] Hart, Kuhlau and Simon (note 11), pp. 660–63.

heavily armed and possessed large quantities of explosives. Several days were spent negotiating with them, but when negotiations stalled Russian authorities used an incapacitating gas to retake the theatre and rescue the hostages. All of the terrorists were killed, but at least 125 hostages died from the effects of the gas.

The Russian people seemed to support the actions of the authorities, but there was much discussion in Russia and elsewhere as to whether the use of the agent had violated the CWC. Russian authorities did not reveal the nature of the gas at the time—which meant that the medical personnel were unable to properly treat the victims of the incapacitating gas—although later they disclosed that a drug related to fentanyl had been used. There has been considerable speculation as to what drug was actually aerosolized (e.g. etorphine, remifentamil or the like). It is also possible that if the antidote, naloxone, had been made available to the medical personnel the loss of life among the hostages would have been minimized.

It is clear that Russia had stockpiled an incapacitating agent for some purpose, military or civilian, and it is possible that the gas used had been developed as part of a chemical warfare capability. During the cold war there was considerable Soviet, as well as US, research on chemicals (e.g. BZ and LSD) that could be used to incapacitate soldiers. Drugs that could induce unconsciousness or euphoria were also studied.

Medication derived from poppies has been used as an anaesthetic for decades and there has been much research to improve the safety of such drugs. Fentanyl was first synthesized in 1960 by the chemist Paul Janssen.[58] It is used together with other drugs to improve the controlled delivery of anaesthesia, but it can cause complications due to respiratory depression.

The question of whether fentanyl and the use of calmatives violates the CWC is difficult. For example, fentanyl is not listed in the schedules of the CWC and its use may fall under 'activities not prohibited' under the convention. RCAs can be used for law enforcement purposes, and it would appear that the use of the opioid by Russian security forces was legitimate.

Malodorants

Malodorants are believed to be permitted under the CWC as riot control agents. The definition of RCAs appears to include malodorants as odorants that affect behaviour and act as sensory irritants, similar to other RCAs. In the words of one definition, malodorants use: 'olfactory stimuli to change and control behaviour for modern warfare' with the aim of 'taking the fight out and incapacitating the

[58] Schulz, W., 'Fentanyl', *Chemical & Engineering News*, 20 June 2005, <http://pubs.acs.org/cen/coverstory/83/8325/8325fentanyl.html>.

perpetrator'.[59] In 1944 the US National Defense Research Committee (NDRC) produced a strong, lasting skatolic (faecal) odour for use in France and Japan.[60] The NDRC stated in 1997 that a large 'odour atlas' was available and that it could duplicate any odour required. It could also use micro-encapsulation to allow for the delayed release of malodorants.[61]

The US Defense Advanced Research Projects Agency (DARPA) has also attempted to identify culturally specific malodorants. The odours tested include US Government Standard Bathroom Odor, butyric acid, vomit odour, sewage odour, burned hair, cherry–almond, cinnamon, lemon, menthol and vanilla, all of which have been given an 'odor repellency ranking'.[62] The Monell Chemical Senses Center serves as a research partner in these studies.[63]

Since many malodorants mimic toxins, legal aspects of their development and possible use should be considered within the framework of the BTWC.

Oleoresin capsicum

OC is an oily extract of pepper plants of the genus capsicum. The extract is used in foodstuffs and as a pharmacologic agent in topical anaesthetics and analgesic creams. It is also the principal active ingredient in OC spray and is a mixture of complex soluble phenols known as capsaicinoids. Capsaicin (trans-8-methyl-N-vanillyl-6-nonenamide) and dihydrocapsaicin make up 80–90 per cent of the substance. The amount of oleoresin capsicum in pepper spray varies widely from about 1.2 per cent to 12.6 per cent, and the concentration of the pepper extract varies from 5 per cent to 15 per cent (i.e. the resulting exposure risk varies by thirtyfold).[64] There is also a synthetic version, VN, that has various chemical names: N-vanillyl nonanamide, pelargonylvanillylamide and nonivamide. It is commonly known as PAVA.[65] Capsaicin is at least 15 times less toxic than VN.

[59] Science Applications International Corporation, 'Less-than-lethal systems: situational control by olfactory stimuli', White Paper submitted to Marine Corps System Command, Joint Non-Lethal Directorate, Quantico, VA, June 1998.

[60] National Defense Research Committee, Division 19, 'Final Report on Who Me?', contract OEMsr-1023, 19 Dec. 1944; and National Defense Research Committee, Division 19, 'Supplement to Final Report on Who Me?', contract OEMsr-1023, 19 Feb. 1945.

[61] US Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, 'Odorous substances', July 1997, available at <http://www.sunshine-project.org/>.

[62] Bickford, L. et. al., 'Odorous substances for non-lethal application', Presentation at NDIA Non-Lethal Defense IV Conference, Tysons Corner, VA, 20–22 Mar. 2000, <http://www.dtic.mil/ndia/nld4/bickford.pdf>.

[63] Trivedi, B. P., 'U.S. military is seeking ultimate "stink bomb"', National Geographic Today, 7 Jan. 2002, <http://news.nationalgeographic.com/news/2002/01/0107_020107TVstinkbomb.html>; and Davison, N. and Lewer, N., Bradford Non-Lethal Weapons Research Project Research Report no. 4, Dec. 2003, <http://www.bradford.ac.uk/acad/nlw/research_reports/>.

[64] Busker, R. W. and van Helden, H. P., 'Toxicologic evaluation of pepper spray as a possible weapon for the Dutch police force: risk assessment and efficacy', *American Journal of Forensic Medicine,* vol. 19, no. 4 (Dec. 1998), pp. 309–16.

[65] Zarc International Incorporated, 'News and alerts: VN (synthetic capsaicin)', <http://www.zarc.com/english/news/vn.html>.

Table 3.3. Pungency effect of select agents

Name	Scoville heat units
Capsaicin (natural)	16 000 000
Dihydrocapsaicin	16 000 000
Nordihydrocapsaicin	9 100 000
Homocapsaicin	8 600 000
Homodihydrocapsaicin	8 600 000
N-Vanillyl octanamide	8 000 000
N-Vanillyl nonanamide (VN)	9 200 000
N-Vanillyl decanamide	4 500 000
N-Vanillyl undecanamide	3 500 000
N-Vanillyl paaiperic acid amide	1 500 000

Source: Author compilation.

Pungency is measured in Scoville heat units and natural capsaicin is much more potent than VN (i.e. VN has a higher toxicity, is less pungent and causes less pain than natural capsaicin, see table 3.3).

A detailed quantitative analysis of capsaicinoids has been conducted,[66] and other chemical analyses have been carried out on Cap-Stun, Safstun and Peppermace.[67] A study dealing with exposure to various defence sprays has also been carried out.[68]

Oleoresin capsicum has more or less replaced Mace as a personal defence spray and there are hundreds of suppliers in North America. It is the newest and least researched spray. Initial research was conducted at Edgewood Arsenal in the 1960s, and it was introduced into use by the US Postal Service as a dog repellent (and against bears in Canada). The US Federal Bureau of Investigation (FBI) uses the Cap-Stun brand. Although its overall effectiveness has been disputed, the Canadian Police Research Centre concluded that the brand was 'totally effective for use to incapacitate a suspect' in over 93 per cent of cases reviewed (over 100).[69]

There are many manufacturers of OC, which makes assessing the concentration of active ingredients of pepper spray products difficult because their composition

[66] Reilly, C. A., Crouch, D. J. and Yost, G. S., 'Quantitative analysis of capsaicinoids in fresh peppers, oleoresin capsicum and pepper spray products', *Journal of Forensic Sciences*, vol. 46, no. 3 (May 2001), pp. 504–509.

[67] Canadian Police Research Centre, *Chemical Analysis of Oleoresin Capsicum Products*, Technical Report no. TR-07-92 (Natural Research Council Canada: Ottawa, Mar. 1992), <http://www.cprc.org/tr/tr-1992-07.pdf>.

[68] Lee, R. J. et al., 'Personal defense sprays: effects and management of exposure', *Journal of the American Optometric Association*, vol. 67, no. 9 (1996) pp. 548–60.

[69] DeWitt, D., 'The power and controversy of pepper sprays', Fiery-Foods.com, <http://www.fiery-foods.com/dave/peppparspray.html>; and British Columbia Police Commission, *TM–01–90 Cap-Stun-Capsicum Spray* (Canadian Police Research Centre: British Columbia, July 1990), p. 2.

differs from manufacturer to manufacturer. In addition, solvents may interact with the pepper ingredients. Most manufacturers do not disclose the exact composition of the product, and their material safety data sheets (information about a substance's properties) also state that the composition is a trade secret. DuPont Chemicals, for example, describes its Dymel 22 propellant in the following terms: 'the compound is untested for skin and eye irritancy and is untested for animal sensitization'.[70]

The controversy over the use of pepper spray

The use of pepper as a law enforcement technique was described in India in 1872, and a notable use of tear gas occurred in the Great Lumber Strike of 1935 in the Pacific Northwest of the USA. There is a long history of the use of tear gas on non-violent protesters and in response to rioting.

The use of OC against non-violent protesters continues to be controversial. Law enforcement authorities say that there are no long-term effects, but those subjected to pepper spray disagree. In addition, it would appear that the police periodically disregard the instructions on the use of the sprays (i.e. they deliberately target the eyes and from an unsafe distance, including by swabbing the eyes of non-violent protesters).[71] Similar situations occurred in Vancouver during the summit meeting of the leaders of the Asia–Pacific Economic Cooperation (APEC) in November 1997.[72] The expected demonstrations occurred but things went wrong and there were many complaints of police misconduct, including their use of pepper sprays.

In April 2001 Quebec City hosted the third Summit of the Americas where some 30 heads of state discussed a proposed Free Trade Area of the Americas.[73] Around 35 000 anti-globalization protestors were present as were approximately 5000 police officers from the Royal Canadian Mounted Police (RCMP), the Quebec provincial police (Sûreté du Québec) and various municipal forces.[74] About 5000 to 10 000 protesters were involved in direct action protests. Tear gas was used against the protesters, and the 'public watchdog' overseeing the RCMP, the Commission for Public Complaints Against the RCMP, condemned the police tactics. The commission reported that: 'RCMP members used excessive and

[70] Zarc International Incorporated, 'Consumer alert: DuPont cautions against use of HCFC Dymel in pepper sprays', 20 Aug. 1993, <http://www.capstun.com/english/news/dupontdymell.html>.

[71] Amnesty International, 'Document—USA: ruling limiting police use of pepper spray—a positive step', 17 May 2000, <http://www.amnesty.org/fr/library/asset/AMR51/072/2000/en/dom-AMR510722000en.html>.

[72] Pue, W. W., 'Executive accountability and the APEC inquiry: comment on "ruling on applications to call additional government witnesses"', *British Columbia Law Review*, vol. 34 (2000), pp. 335–44.

[73] See the Free Trade Area of the Americas website, <http://www.ftaa-alca.org/alca_e.asp>.

[74] Leroux, D., 'Canada: Quebec set to crack down on FTAA protests', CorpWatch, 20 Feb. 2001, <http://www.corpwatch.org/article.php?id=175>.

unjustified force in releasing tear gas to move the protesters'.[75] The RCMP had not followed appropriate procedures before using tear gas, lasers and flash grenades.

A report from Dugway Proving Ground states that OC is a useful alternative to force since tear gases are not consistently effective and that OC is preferred by law enforcement agencies; the report also discusses problems associated with several of the methods of distribution.[76] Zarc International Incorporated has also defended the safety of its product Cap-Stun, although its report notes that 'Zarc cannot speak about other pepper sprays'. [77] The report concludes that pepper spray was not a factor in any of the reported deaths of arrested suspects in custody and that something else caused the subjects to die.

The US Department of Justice's National Institute of Justice has carried out at least two reviews of pepper spray.[78] The first study, whose authors worked for the International Association of Police Chiefs at the time, discusses the advantages of OC over other sprays and its advantages for law enforcement agencies. The second review discusses unpublished studies by the National Institute of Justice on police and suspect injuries and in-custody deaths and suggests that pepper spray inhalation did not pose a significant risk.

The USA considers OC to be a riot control agent. US policy on RCAs allows for their use in an 'armed conflict' provided that presidential approval has been granted. However, RCAs may not be used in armed conflict except in 'defensive military modes to save lives'.[79]

In 1995 the American Civil Liberties Union (ACLU) of Northern California summarized the history of OC use and the problems associated with such use. OC was authorized for use in 1992 by law enforcement agencies and against civilians in March 1994; by May 1995 it had been used 16 000 times in California. In the

[75] 'RCMP used "excessive" force at summit: watchdog', CTV National News with Lloyd Robertson, 14 Nov. 2003, <http://www.ctv.ca/servlet/ArticleNews/story/CTVNews/20031114/rcmp_report_summit_americas_031113?s_name=&no_ads=>.

[76] See excerpts from Nicholson, P., 'Oleoresin capsicum: an effective less-than-lethal riot control agent', Jan. 1997, at Zarc International Incorporated, <http://www.zarc.com/english/cap-stun/reports/dugway report.html>; and Steffee, C. et al., 'Oleoresin capsicum (pepper) spray and "incustody deaths"', *American Journal of Forensic Medicine and Pathology*, vol. 16, no. 3 (1995).

[77] Zarc International Incorporated, 'Questions and answers about pepper spray safety', <http://www.capstun.com/english/news/peppersafety.html>.

[78] Edwards, S. M., Granfield, J. and Onnen, J., 'Evaluation of pepper spray', US Department of Justice, National Institute of Justice, *Research in Brief*, Feb. 1997, <http://www.ojp.usdoj.gov/nij/pubs-sum/162358.htm>; and US Department of Justice, National Institute of Justice, 'The effectiveness and safety of pepper spray', Apr. 2003, <http://www.ncjrs.gov/pdffiles1/nij/195739.pdf>. See also US Department of Justice, National Institute of Justice, 'Less-lethal technologies', <http://www.ojp.usdoj.gov/nij/topics/technology/less-lethal/welcome.htm>.

[79] US National Archives and Records Administration, 'Executive Order 11850—renunciation of certain uses in war of chemical herbicides and riot control agents', 8 Apr. 1975, <http://www.archives.gov/federal-register/codification/executive-order/11850.html>. See also US Army, Judge Advocate General's Legal Center and School, 'Operational law handbook', Charlottesville, VA, 25 June 2007, <http://www.fas.org/irp/doddir/army/law2007.pdf>, p. 20.

first two years of its use there were 26 deaths—1 for every 600 uses by police—and nearly one-third of the uses resulted in litigation. It is clear that the agencies were not following the manufacturers' recommendations for use (i.e. one-second bursts). In 1994 the California Environmental Protection Agency stated that: 'OC may have been a contributing cause of death or exacerbated underlying conditions such as pre-existing disease or drug use, to cause cardiac or respiratory failure'.[80] The FBI has stated, however, that there was no reason to doubt the findings of its Firearms Training Unit study of the effects of OC use.[81]

The safety of OC is disputable and no studies have been made of the effects of long-term exposure on law enforcement personnel. The claims that OC played no role in the more than 60 deaths that have been reported have also been questioned.[82]

[80] American Civil Liberties Union (ACLU), 'Pepper spray update: more fatalities, more questions', June 1995, <http://www.aclu-sc.org/attach/p/Pepper_Spray_New_Questions.pdf>, p. 3.

[81] Zarc International Incorporated, Letter from Howard M. Shapiro addressed to Alan Parachini, ACLU Foundation of Southern California, 17 May 1996, <http://www.zarc.com/english/news/fbiaclu.html>.

[82] See Association of Defensive Spray Manufacturers, 'Selective bibliography of studies about defensive sprays', <http://www.pepperspray.org/bibliography.htm>; and 'Defense (pepper) spray laws and restrictions', Personalsafetysecurity.com, <http://www.personalsafetysecurity.com/defense_spray_laws.htm>.

4. Disabling biochemical substances and synthetic biology

Research by the military and law enforcement agencies has focused on incapacitants, calmatives and anti-materiel agents. The anti-materiel agents studied have usually been microbes that were genetically altered to produce enzymes that have the ability to degrade substances including lubricants, fuels, paint, plastics and even cement.[83] These developments have been the subject of numerous critical reviews.[84] Since 1997 the Bradford Non-Lethal Weapons Research Project has also reviewed numerous potential 'non-lethal' weapons.[85] Another report, the BioWeapons Prevention Project's *BioWeapons Report* covers the period 2002–2004 and includes a detailed chronology.[86]

All of the pharmaceutical compounds that have been investigated as incapacitants have a significant potential lethality, as the 2002 incident at Moscow's Dubrovka Theatrical Centre demonstrated.[87] Depending on the drug used, the effects of the use of such agents are delirium, unconsciousness and agitation, and the safety factor is almost always much smaller than that anticipated in normal medical usage.

The problem noted by the BTWC negotiators was that developments in the biological sciences have moved the focus from pathogens and toxins developed by past state military programmes to effects on biochemical processes within the body. In neuroscience, for example, there is now detailed knowledge of the peptide neurotransmitters that are involved in chemical transmission through the nervous system in addition to acetylcholine, and genomics has led to understanding of various receptor systems that are now the targets of therapeutic drugs.[88] The technology of combinatorial chemistry has also led to increased speed in drug identification (i.e. the identification of compounds that affect

[83] Center for Arms Control and Non-Proliferation, 'Disabling biochemical weapons', <http://www.armscontrolcenter.org/cbw/disabling/>.

[84] Wheelis, M., '"Non-lethal" chemical weapons: a Faustian bargain', Issues on line in Science and Technology, spring 2003, <http://www.issues.org/19.3/wheelis.htm>; Wheelis, M., 'Will the new biology lead to new weapons', *Arms Control Today*, vol. 34, no. 6 (July/August 2004), pp. 6–13; Tucker, J. B., 'Biological threat assessment: is the cure worse than the disease', *Arms Control Today*, vol. 34, no. 8 (Oct. 2004), pp. 13–19; and Davison, N., 'Biochemical weapons: lethality, technology, development and policy', May 2004, Bradford Non-Lethal Weapons Research Project, <http://www.brad.ac.uk/acad/nlw/research_reports/>.

[85] Davison, N. and Lewer, N., Bradford Non-Lethal Weapons Research Project Research Report no. 6, Oct. 2004, <http://www.bradford.ac.uk/acad/nlw/research_reports/>.

[86] BioWeapons Prevention Project, 'BioWeapons report 2004', 2004, <http://www.bwpp.org/publications.html>.

[87] See Hart, Kuhlau and Simon (note 11).

[88] Dando, M., 'Future incapacitating chemical agents: the impact of genomics', ed. N. Lewer, *The Future of Non-Lethal Weapons. Technologies, Operations, Ethics and Law* (F. Cass: London, 2002).

specific receptor sites). These developments are two edged in that they are 'dual use' and can, in principle, be used to develop weapons if not properly controlled.[89] BTWC and CWC implementation practice must take such factors into account (as opposed to overly focusing on listed CWC agents or 'traditional' biological pathogens investigated by former state CBW programmes).

Graham Pearson's chemical and biological weapon spectrum (figure 4.1) is a useful conceptual device because it shows biological and chemical weapons as a continuum and draws attention to the overlap between the BTWC and the CWC, as well as highlighting some of the uncertainties regarding legal prohibitions. With the rapid pace of modern developments it is also more difficult to decide whether the BTWC or the CWC is applicable. Classical toxic chemicals are clearly the province of the CWC, but new ways of discovering drugs and their methods of action lead to a blurring of the categories of pharmaceutical chemicals, bio-regulators and toxins. In addition, because chemists, biochemists and biologists can synthesize bioregulators, toxins and their analogues, the CWC and its verification methodology should apply. Mark Wheelis has used the term 'biochemical weapons' to underline these problems. It is essential that these weapons not escape the restrictions of the BTWC and the CWC despite the practical limitations of both conventions.

The potential use of bio-regulators, either in warfare or by terrorists, is disturbing. Bio-regulators of possible concern are, among others, cytokines, eicosanoids (a type of signalling molecule), neurotransmitters and hormones. Neurotransmitters play a role in regulating consciousness, cognition, reception and anxiety. Neurotransmitters occur naturally but there are also synthetic analogues, and they were included in the study conducted by Pennsylvania State University.[90]

Advanced technologies accelerate the drug discovery process, as in the case of combinatorial chemistry, toxicogenomics, database mining, genomics and proteomics. A detailed report covering animals, plants and future threats has pointed out that in the future an increasing range of biological agents may exist that could be used for hostile purposes.[91] Professor Matthew Meselson of Harvard University has argued that many more of life's fundamental processes are now open to malign modifications.[92]

It is clear that new biological warfare agents can be made from plant pathogens and it is possible to specifically engineer a pathogen that is lethal to a wide range

[89] Dando, M., 'The danger to the Chemical Weapons Convention from incapacitating chemicals', CWC Review Conference Paper no. 4, University of Bradford, Department of Peace Studies, Mar. 2003.

[90] Hammond, E., 'Bombing the mind: the Pentagon's program for psychopharmalogical warfare', *Counterpunch*, 2 July 2002; and Lakoski, Murray and Kenny (note 33).

[91] Nixdorff, K. et al., 'Technology and biological weapons: future threats', Science and Technology Report no. 2, Bradford Non-Lethal Weapons Research Project, 2004, <http://www.brad.ac.uk/acad/nlw/publications/>.

[92] Meselson, M. and Kaysen, C., 'The problem of biological weapons', 1818th Stated Meeting of American Academy of Arts & Sciences, 13 Jan. 1999, quoted in American Academy of Arts & Sciences, 'Recent events', <http://www.amacad.org/events/recent1999.aspx>.

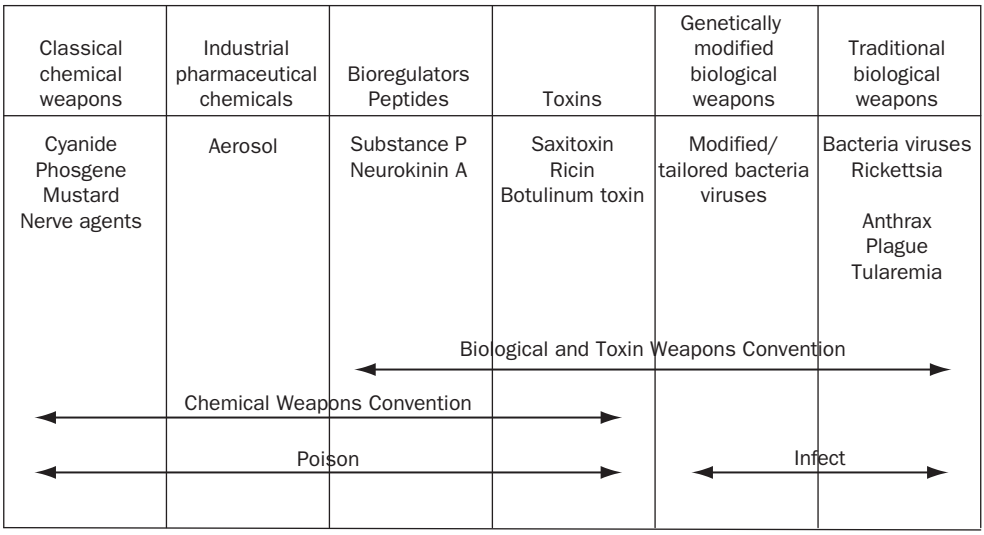

Figure 4.1. The chemical and biological weapon spectrum

Source: Pearson, G., 'Relevant scientific and technological developments for the first CWC Review Conference', CWC Review Conference Paper no. 1, 2002, University of Bradford, Department of Peace Studies.

of organisms. Modern agriculture is particularly vulnerable to plant pathogens because of its reliance on monoculture and a restricted range of gene types.

Synthetic biology

In 2003 the US Central Intelligence Agency issued an unclassified report by a group of life scientists for the Strategic Assessments Group.[93] It concludes that advances in biotechnology and the difficulty of detecting dangerous biological activity had increased the possibility of biological threats, including those posed by 'designer' biological warfare agents and unnatural pathogens.

Currently available synthetic genomics technology allows scientists to reconstruct genes or whole genomes of sequenced microorganisms. While the technical capacities of genetic synthesizers allow increasingly larger segments to be constructed, the costs are continually dropping. In addition, as the complexity and application of synthetic genomics expands rapidly, biologists are on the threshold of being able to synthesize new life forms and, therefore, the potential for misuse of these technologies increases. For example, live infectious polio virus has been assembled from mail-order oligonucleotides using a viral genome

[93] Central Intelligence Agency, 'The darker bioweapons future', 3 Nov. 2003, <http://www.fas.org/irp/cia/product/bw1103.pdf>.

map available on the Internet—a process that took about two years.[94] The bacteriophage, Φx174 (5386bp [base pairs] long) was assembled in 2003 from synthetic oligonucleotides within two weeks,[95] and in 2005 the US Centers for Disease Control and Prevention (CDC), the Armed Forces Institute of Pathology and the Mount Sinai School of Medicine synthesized the Spanish influenza virus that was responsible for the deaths of 50–100 million people in the 1918–19 influenza pandemic.[96] At the J. Craig Venter Institute, researchers have worked on identifying the 'minimal genome' of a bacteria that would provide the minimum necessary machinery to sustain life.

Other examples of groundbreaking developments include the alteration of the natural amino acids, changing their basic properties to provide increased stability towards degradation as well as changing their different catalytic and binding properties.[97] Jay Keasling is using synthetic biology to develop an effective method of producing artemisinic acid in modified yeast, which has been successfully used in the treatment of malaria.[98] Other therapeutic compounds such as the chemotherapy drug taxol and the promising anti-HIV compound prostratin are candidates for production through the use of synthetic genomics. Also an artificial metabolic pathway is being sought for producing biofuels from cellulose by specially designed synthetic enzymes.[99]

A programme—the Registry of Standard Biological Parts—is currently in place to allow the standardization of genetic parts with reliable characteristics. Genetic parts of known behaviour are referred to as BioBricks. There are currently 167 basic parts and 421 composite parts available on the programmme website, while a further 50 parts are under construction.[100] The principal objective of the pro-

[94] Cello, J., Paul, A. V. and Wimmer, E., 'Chemical synthesis of poliovirus cDNA generation of infectious virus in the absence of natural template', *Science*, vol. 297 (2002), pp. 1016–18.

[95] Smith, H. O. et al., 'Generating a synthetic genome by whole genome assembly Φx174 bacteriophage from synthetic oligonucleotides', *Proceedings of the National Academy of Sciences*, vol. 100, no. 26 (2003), pp. 15440–45.

[96] Tumpev, T. M. et al., 'Characterization of the reconstructed 1918 Spanish influenza pandemic virus', *Science*, vol. 310, no. 5745 (2005), pp. 77–80. For background see Barry, J. M., *The Great Influenza: the Epic Story of the Deadliest Plague in History* (Penguin Books: London, 2004).

[97] Switzer, C., Moroney, S. E. and Benner, S. A., 'Enzymatic incorporation of a new base pair into DNA and RNA', *Journal of the American Chemical Society*, vol. 111, no. 21 (11 Oct. 1989), pp. 8322–23.

[98] Martin, V. J. J. et al., 'Engineering a mevalonate pathway in *Escherichia coli* for production of terpenoids', *Nature Biotechnology*, vol. 21, no. 7 (July 2003), pp. 796–802; Tucker, J. B. and Zilinskas, R. A., 'The promise and perils of synthetic biology', *New Atlantis*, no. 12 (spring 2006), pp. 25–45; and 'Life 2.0', *The Economist*, 2–8 Sep. 2006, pp. 68–70.

[99] Sedlak, M. and Ho, N. W. Y., 'Production of ethanol from cellulosic biomass hydrolysates using genetically engineered Saccharomyces yeast capable of cofermenting glucose and xylose', *Applied Biochemistry and Biotechnology*, vol. 113–116 (2004), pp. 403–16.

[100] See the Registry of Standard Biological Parts website, <http://partsregistry.org/Main_Page>; and the BioBricks Foundation website <http://bbf.openwetware.org/>. The BioBricks Foundation is a non-profit organization founded by engineers and scientists from the Massachusetts Institute of Technology, Harvard University and the University of California, San Francisco. It 'encourages the development and responsible use of technologies based on BioBrick standard DNA parts that encode basic biological functions'.

gramme is to develop a methodology for the assembly of BioBricks into 'circuits' for practical applications. Doing so will open the field of biology to engineers.

Synthetic biology has reinvigorated genetic engineering and has made many significant discovers in a short period of time, including those that led to the development of synthetic genomics, protein design, natural product synthesis and genetic circuits based on BioBricks. Through the use of synthetic biology, scientists will shortly have the potential to develop new entities that can reproduce and evolve. George Church sounded a warning about the significant problems related to these endeavours: 'A code of ethics should emerge for biological engineering as it has done for other engineering disciplines'.[101] Church also suggested practical steps: physical isolation and biological isolation to reduce the viability of the biological systems created, and a requirement that genetic strains have essential nutrients that are unavailable in nature. In other words, the focus should be on the potential risks related to the use of synthetic genomics in developing pharmaceuticals, biomaterials and integrated genetic circuits.[102]

Gene synthesis technology has the capacity to make viruses (i.e. it is theoretically possible for bioterrorists to order dangerous DNA sequences through the post in order, for example, to make smallpox virus or other lethal pathogens). It is unlikely that any terrorist group has the skills necessary at present but the technology is becoming simpler. There clearly is a need for self-regulation and government interaction as well as public scrutiny.

One of the greatest areas of concern in synthetic biology is the ability to create 'synthetic life' (i.e. life that can replicate itself). Scientists can now create replicas of existing pathogens. It may also be possible to synthesize genotype-specific weapons that could target animals or plants (many plants are produced as monocultures today). The potential combination of synthetic biology with nanotechnology promises even more challenges in the future. Hence there is a need to develop policy to address such issues and to modify existing international practices to prevent proliferation.

The practitioners of synthetic biology are aware of the potential problems associated with their work and there have been many discussions of the potential risks. The outcome of the 1975 International Congress on Recombinant DNA Molecules (Asilomar Conference) has been periodically reviewed for guidance on how to proceed safely.[103] The risks associated with recombinant DNA technology have been classified as related to three areas: accidental release, use in the environment, and misuse for hostile purposes.

George Poste, a former member of the US National Academy Sciences Working Group on Biological Weapons, has developed a 'calculus of risk' to enable the

[101] Church, G., 'Let us go forth and safety multiply', *Nature*, 24 Nov. 2005, p. 423.

[102] 'Study to explore risks, benefits of synthetic genomics', MIT News, 28 June 2005, <http://web.mit.edu/newsoffice/2005/syntheticbio.html>.

[103] Asilomar Conference on Recombinant DNA Molecules, 'Summary statement', 20 May 1975, <http://profiles.nlm.nih.gov/QQ/B/C/G/D/_/qqbcgd.pdf>.

enumeration of threats posed by developments in order to ascertain when a threshold has been reached.[104] Sooner or later synthetic biology may find itself facing risks that are not hypothetical.

After much debate in the synthetic biology community, a draft declaration was developed outlining the discussion on bio-security and bio-safety issues.[105] However, a group of 38 international organizations objected to this attempt at self-regulation and self-governance by a voluntary code.[106] Ultimately, the researchers in the field of synthetic biology did not adopt the controversial code of conduct that had been intended to prevent their technologies being used to make bioweapons.[107]

Roger Brent, a geneticist, has stated that DNA hacking has reached the point where a laboratory assistant with the right resources could do the job (i.e. a bioterrorist would not need a team of virologists and state funding).[108] A 2005 article considered the bioterrorism risks stemming from a failure to carrying out checks on customer credentials.[109] Sixteen 'test' requests were submitted to firms that are involved in gene synthesis: of the 12 replies only 5 stated that they screen all requests; 4 said that they screen some; and 3 screen none at all (i.e. a terrorist could order building blocks for a weapon and receive them through the post).

In response to a question about the bioterrorist problem, Drew Endy, a leader in the field of synthetic biology, stated: 'It is irresponsible to develop any technology without addressing the associated non-technical issues. For example not all DNA synthesis companies check what they make'.[110] A British Royal Society policy document on science and technology developments of relevance to the BTWC addresses synthetic biology.[111] It notes that the technique is available

[104] Poste, G., 'Synthetic biology: charting rational public policies for the oversight and regulation of vanguard technologies', Presentation at Massachusetts Institute of Technology, 11 June 2004, <http://www.openwetware.org/images/3/3a/SB1.0_George.Poste.pdf>.

[105] The World Health Organization defines laboratory bio-security as 'the principles, technologies and practices implemented to secure pathogens, toxins and sensitive technology from unauthorized access, loss, theft, misuse, diversion or intentional release'. World Health Organization (WHO), *Biorisk Management: Laboratory Biosecurity Guidance* (WHO: Geneva, Sep. 2006), <http://www.who.int/resources/publications/biosafety/WHO_CDS_EPR_2006_6/en/>. Bio-safety is safety while working with pathogens. See Kuhlau, F., *Countering Bio-threats: EU Instruments for Managing Biological Materials, Technology and Knowledge*, SIPRI Policy Paper no. 19 (SIPRI: Stockholm, Aug. 2007), <http://books.sipri.org/>. For the draft declaration see Second International Conference on Synthetic Biology (SB2.0), Berkeley, Calif., 20–22 May 2006, <http://pbd.lbl.gov/sbconf/>.

[106] etc Group, 'Synthetic biology—global societal review urgent!', Press release, 19 May 2006, <http://www.etcgroup.org/en/issues/synthetic_biology.html>; and International Center for Bioethics, Culture and Disability, 'Open letter: global coalition sounds the alarm on synthetic biology', 19 May 2006, News release, <http://www.bioethicsanddisability.org/syn2.html>.

[107] Aldhous, P., 'Synthetic biologists reject controversial guidelines', *New Scientist*, 23 May 2006.

[108] Boutin, P., 'Biowar for dummies', Paul Boutin blog, 22 Feb. 2006, <http://research.lifeboat.com/biowar.htm>.

[109] Aldhous, P., 'The bioweapon is in the post', *New Scientist*, 9 Nov. 2005.

[110] Singer, E., 'Keeping synthetic biology away from terrorists', *Technology Review*, 6 July 2006.

[111] British Royal Society, 'Report of the international workshop on science and technology developments relevant to the BTWC', 16 Nov. 2006, <http://royalsociety.org/document.asp?tip=0&id=5563>.

commercially worldwide, that genetic material can be ordered by post, and that DNA synthesizers can be ordered on the Internet. The policy document stresses that the potential dual risks of synthetic biology are high and that there is insufficient knowledge of relevant national and international laws and regulations.

In 2007 the J. Craig Venter Institute, the Center for Strategic and International Studies and the Massachusetts Institute of Technology's Department of Biological Engineering issued a report examining the safety and security concerns posed by synthetic genomics.[112] It identifies three main points for possible policy intervention: (*a*) commercial firms that sell synthetic DNA (oligonucleotides, genes or genomes) to users; (*b*) owners of laboratory 'bench-top' DNA synthesizers, with which users can produce their own DNA; and (*c*) the users (consumers) of synthetic DNA and the institutions that support and oversee their work.[113]

For each point, the report suggests procedures to confirm that materials, equipment and expertise are not misused. For example, commercial firms should use approved software to screen orders, and they should retain information on customers and their orders. The report also recommends that the responsibility of institutional bio-safety committees should be broadened to evaluate 'risky' experiments. However, great scope remains in how to interpret and implement the options identified in the Venter report. For example, the definition of terms in the report and their application would almost certainly be disputed. How responsibility is allocated in practice might also be controversial. More generally, some states may question the suitability or appropriateness of applying such security-oriented (as opposed to safety-oriented) guidelines at the international level.

[112] Garfinkel, M. S. et al., 'Synthetic genomics: options for governance', J. Craig Venter Institute, Center for Strategic and International Studies and the Massachusetts Institute of Technology's Department of Biological Engineering, Oct. 2007, <http://www.jcvi.org/research/synthetic-genomics-report/>.

[113] Garfinkel et al. (note 112), p. ii.

5. Conclusions and recommendations

Maintaining the effectiveness of international prohibitions against chemical and biological weapons

The US military is pursuing a strategy for the development of a continuum of weapons from lethal to less lethal and, perhaps, even non-lethal weapons. However, weapons based on chemistry, biology and biochemistry cannot be considered non-lethal. The term 'weapons of mass protection' is coming into use where:

> nonlethality is the use of weapons of mass protection such as nonlethal and antilethal weapons and information warfare to project high-precision power in a timely fashion, delivering results that are life conserving, environmentally friendly, and fiscally responsible. Such weapons can provide airpower with capabilities that will yield new supports to diplomacy, a credible deterrent below the level of massive conventional force projection, and an expanded ability to meet evolving mission needs when used in conjunction with conventional force.[114]

Their use is said to give the ability to 'non-lethally' overcome an enemy who is using lethal force, and taking such an approach will be a requirement for peacekeeping, peace enforcement and operations other than war.

Advances in biological science have moved progressively away from the difficulties associated with the control of microbes to those associated with influencing fundamental processes of human physiology. Such advances must be covered by international law, including not only the BTWC and the CWC, but also other regimes such as the Montreal Protocol and the 1977 Enmod Convention.[115]

The ethical dimension of the use of non-lethal weapons must also be considered. International law regulates the conduct of war—the use of force must be proportionate to the threat and the ends pursued. The use of NLWs is a 'slippery

[114] Morris, C., Morris, J. and Baines, T., 'Weapons of mass protection: nonlethality, informative warfare and airpower in the age of chaos', *Airpower Journal* (spring 1995).

[115] The Montreal Protocol on Substances that Deplete the Ozone Layer was opened for signature in 1987 and entered into force on 1 Jan. 1989. It has been amended 5 times (1990, 1992, 1995, 1997 and 1999). There are 191 parties. The protocol addresses halogenated hydrocarbons that cause ozone depletion and involve substances containing chlorine and bromine (but not fluorine). There is a timetable for their eradication. This elimination is done by individual states parties and a multilateral fund is provided to developing countries to help them phase out ozone-depleting substances that are commonly used in refrigeration, foam extrusion, industrial cleaning, fire safety and fumigation. The text of the protocol is available at <http://ozone.unep.org/Treaties_and_Ratification/2B_montreal_protocol.asp>.

For a summary of the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques see appendix A. Enmod was inspired by the use of Agent Orange and other environmental modification agents during the Viet Nam War. It does not cover environmental damage caused by war.

slope' that can result in increasing and unwanted involvement in a larger scale conflict.

The Federation of American Scientists Working Group on Biological Weapons has expressed concern about the use of NLWs.[116] The group notes that developments in biology and chemistry show that the process of drug development has become less empirical and more rational. It discusses the technologies of combinatorial chemistry, genomics, micro-arrays, proteomics and toxiogenomics; database mining; and the acceleration of the understanding of physiological responses. The group has also highlighted concerns regarding incapacitating agents, which are of great interest to the military and law enforcement agencies. In spite of claims that NLWs are non-lethal, they are responsible for a considerable number of casualties (e.g. at least 125 or approximately 15 per cent of the hostages in the 2002 incident at a theatre in Moscow[117]). A major worry is their potential adjunct (i.e. 'force multiplier') to lethal force and the collaboration between the military and police forces.

Neil Davison has considered the issue of lethality and, in his view, incapacitants cannot be considered as 'non-lethal' because they possess a lethality that is comparable to that of conventional weapons—especially when the problems of dose delivery to an inhomogeneous group of the elderly, the young, the pregnant and the ill are taken into account.[118] Incapacitants cannot be considered to be RCAs under the CWC because the potential new biochemical agents can be lethal.

Various experts have presented their views on NLWs. Brian Rappert has discussed the interests of the police and military in the West and the components that are needed to properly evaluate such weapons.[119] George Poste has addressed the problems of dual-use technology and has expressed the view that science has gone 'beyond bugs' to the 'brain bomb' 'as we begin to understand the exquisite molecular mechanisms that regulate this remarkable structure called the human body or, indeed, plant and animal function as well, the ability to understand these circuits means that simultaneously we gain the capacity to scramble them'.[120]

Policy recommendations

The relevant authorities and observers should consider the following steps.

[116] Anonymous, 'Non-lethal chemical and biological weapons', Federation of American Scientists Working Group on Biological Weapons, Nov. 2002, <http://www.fas.org/bwc/papers.htm>.

[117] See Hart, Kuhlau and Simon (note 11).

[118] Davison, N. and Lewer, N., Bradford Non-Lethal Weapons Research Project Research Report no. 5, May 2004, <http://www.brad.ac.uk/acad/nlw/research_reports/>.

[119] Rappert, B., 'Sceptical appraisals: a proposed framework for the assessment of non-lethal weapons', *Medicine, Conflict & Survival*, vol. 20 (2004), pp. 35–54.

[120] Poste, G., 'Advances in biotechnology: promise and peril', Second National Symposium on Medical and Public Health Response to Bioterrorism, Center for Biosecurity, Washington, DC, 28–29 Nov. 2000.

The parties to the CWC should further consider their understanding of which chemicals and associated delivery mechanisms are permitted for law enforcement, including for use in possible riot situations. Calls for the establishment of a working group to consider this and related issues are well founded. The working group could also develop criteria for the threshold percentage of deaths or injuries (i.e. above which an NLW is not defined as such), and methodologies to determine the lethality of an NLW and the effects on human health and the environment that are associated with use of an NLW. However, the parties to the CWC may not be able to agree on criteria to determine whether 'types and quantities' of toxic chemicals are consistent with law enforcement purposes. *Such a working group should be tasked to meet specified goals within a given time frame.*

The parties should also consider how a declaration of holdings of chemicals for law enforcement would affect government facilities—as opposed to, for example, the chemical industry. The Technical Secretariat and other appropriate OPCW bodies could perhaps analyse the cost, level of intrusiveness and scope of routine CWC verification under a range of representative scenarios in which some information is made available on the development, production or stocks of chemicals held for law enforcement.

The parties to the CWC have generally attempted to restrict the cost, scope and level of intrusiveness at the operational level. Expanding routine declarations and inspections in order to include chemicals held for law enforcement purposes would also expand the scope and cost of routine verification. However, this would be offset by the progressive elimination of chemical weapon stockpiles. *Chemicals held for law enforcement purposes could be included in declarations and inspections, while inspection resources devoted to the chemical industry could be reduced but more focused.* The Second CWC Review Conference concluded that the allocation of resources to the verification regime for the chemical industry needs to be 'further optimized, taking due account of the nature of the declared facilities, the inspection experience gathered, [and] developments in science and technology'.[121]

Incapacitants can be delivered by biological means. *Thus, the idea to create a subcategory under the CWC verification regime of 'other chemical production facilities' is worthy of serious consideration.*[122] This category would cover facilities that produce peptides. Such facilities produce certain discrete organic chemicals that may contain phosphorus, sulphur or fluorine (DOC/PSFs),[123] but the proposed mechanism would not cover most substances being developed as incapacitants. It might be criticized by those who do not favour routine verification of incapaci-

[121] Organisation for the Prohibition of Chemical Weapons (note 31), para. 9.67, p. 17.

[122] Tucker, J., 'The body's own bioweapons: the next biothreat could come from chemicals derived from the human body that can incapacitate and kill—and which skirt existing arms controls', *Bulletin of the Atomic Scientists*, vol. 64, no. 1 (Mar./Apr. 2008), p. 22.

[123] See CWC (note 4), Verification Annex, Part IX.

tants as 'insufficient', even if the threshold for declaration of such substances were lowered to include university laboratories.[124]

The parties to the BTWC should consider revising the politically binding annual exchanges of information that serve as confidence-building measures to help strengthen the treaty regime by including information on NLWs and similar programmes. Periodic consultations on scientific and technological developments, for example at BTWC review conferences, should also address the issue.

Concluding remarks

The Chemical Weapons Convention will remain central to consideration of issues related to non-lethal weapons. Chemical and biochemical NLWs pose a fundamental policy challenge. How can the use of such weapons—which can reduce the number of deaths and casualties—be reconciled with various legal, ethical and political concerns? The concerns in question include the possible misuse of NLWs to facilitate the killing of targeted individuals and the use of NLW research and development programmes as a cover for an offensive CBW capability or programme.

The legal responsibility for deaths that are caused by the use of NLWs due to poor training or incompetence should be distinguished from responsibility for deaths that result from the deliberate misuse of NLWs. Policy decisions should also take into account the loss of life that could occur if NLWs are not employed.

The focus on chemical and biochemical-based NLWs could be reduced, in part, by replacing them with research and development programmes that concentrate on non-chemical or biochemical systems (e.g. kinetic systems). (The legal implications of such NLW systems should also be evaluated.) Other 'functionally equivalent' non-chemical and biochemical systems may be more appropriate under international law. Developing chemical or biochemical NLW systems that are designed to be used against equipment—rather than humans, animals or plants—may also address some CBW-related concerns. Better training for managing crowds would also meet some of the operational requirements of situations where the use of NLW systems is envisaged.

It would be difficult to implement oversight using lists of biological and chemical substances, and the general purpose criteria of the BTWC and the CWC should be operationalized to assist in this task. Continued political attention must be paid to NLWs and related issues, or current practice may lead to the view that the use of biochemicals is acceptable in a progressively larger variety of circumstances, up to and including certain forms of armed conflict.

[124] 'The expanding range of biowarfare threats', *Bulletin of the Atomic Scientists*, Discussion board, last updated 2 July 2008, <http://www.thebulletin.org/web-edition/roundtables/the-expanding-range-of-biowarfare-threats>.

Appendix A. International law with potential application to non-lethal weapons

Declaration of St Petersburg of 1868 to the Effect of Prohibiting the Use of Certain Projectiles in Wartime

Signed at St Petersburg on 29 November–11 December 1868

The contracting parties engage mutually to renounce, in case of war among themselves, the employment of their military or naval troops of any projectile of a weight below 400 grams, which is either explosive or charged with fulminating or inflammable substances.

Convention on the Laws of War on Land

Signed at The Hague on 18 October 1907; entered into force on 26 January 1910

The convention attempts to codify the general laws and customs of war with a view to either defining them with greater precision or to confining them within such limits as would mitigate their severity to the extent possible. Such laws and customs of war may be relevant where incapacitants or non-lethal weapons are used as 'force multipliers' or in cases where the existence of war and the definition of belligerents are disputed.

Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare (1925 Geneva Protocol)

Signed at Geneva on 17 June 1925; entered into force on 8 February 1928

The protocol declares that the parties agree to be bound by the prohibition on the use of these weapons in war.

Vienna Convention on the Law of Treaties

Signed at Vienna on 23 May 1969; entered into force on 27 January 1980

The convention attempts to support the codification and progressive development of the law of treaties partly in order to promote the purposes of the United Nations Charter, namely the maintenance of international peace and security and the development of friendly relations and the achievement of cooperation among nations. The convention also affirms that the rules of customary international law will continue to govern questions not regulated under the Vienna Convention.

The convention also obliges states to refrain from acts that would defeat the object and purpose of a treaty if it has, inter alia, signed the treaty or expressed its consent to be bound by the treaty pending the treaty's entry into force (and provided the entry into force is not unduly delayed). Any legal argument against the use of incapacitants or non-lethal weapons that is based on customary international law would necessarily be partly based on the provisions of the Vienna Convention.

Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (Biological and Toxin Weapons Convention, BTWC)

Opened for signature at London, Moscow and Washington, DC, on 10 April 1972; entered into force on 26 March 1975

The convention prohibits the development, production, stockpiling or acquisition by other means or retention of microbial or other biological agents or toxins whatever their origin or method of production of types and in quantities that have no justification of prophylactic, protective or other peaceful purposes, as well as weapons, equipment or means of delivery designed to use such agents or toxins for hostile purposes or in armed conflict. The destruction of the agents, toxins, weapons, equipment and means of delivery in the possession of the parties, or their diversion to peaceful purposes, should be effected not later than nine months after the entry into force of the convention for each country. According to a mandate from the 1996 BTWC Review Conference, an ad hoc group is considering verification and other measures to strengthen the convention.

Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (Enmod Convention)

Opened for signature at Geneva on 18 May 1977; entered into force on 5 October 1978

The convention prohibits military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to states party to the convention. The term 'environmental modification techniques' refers to any technique for changing—through the deliberate manipulation of natural processes—the dynamics, composition or structure of the earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space. The understandings reached during the negotiations, but not written into the convention, define the terms 'widespread', 'long-lasting' and 'severe'.

Protocol I Additional to the 1949 Geneva Conventions, and Relating to the Protection of Victims of International Armed Conflicts

Protocol II Additional to the 1949 Geneva Conventions, and Relating to the Protection of Victims of Non-International Armed Conflicts

Opened for signature at Bern on 12 December 1977; entered into force on 7 December 1978

The protocols confirm that the right of parties that are engaged in international or non-international armed conflicts to choose methods or means of warfare is not unlimited and that it is prohibited to use weapons or means of warfare that cause superfluous injury or unnecessary suffering.

Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons which may be Deemed to be Excessively Injurious or to have Indiscriminate Effects (CCW Convention, or 'Inhumane Weapons' Convention)

The convention, with protocols I, II and III, was opened for signature at New York on 10 April 1981; entered into force on 2 December 1983

The convention is an 'umbrella treaty', under which specific agreements can be concluded in the form of protocols. In order to become a party to the convention a state must ratify at least two of the protocols.

The amendment to Article I of the original convention was opened for signature at Geneva on 21 November 2001. It expands the scope of application to non-international armed conflicts. The amended convention entered into force on 18 May 2004.

Protocol I prohibits the use of weapons intended to injure by fragments which are not detectable in the human body by X-rays.

Protocol II prohibits or restricts the use of mines, booby-traps and other devices.

Amended Protocol II, which entered into force on 3 December 1998, reinforces the constraints regarding landmines.

Protocol III restricts the use of incendiary weapons.

Protocol IV, which entered into force on 30 July 1998, prohibits the employment of laser weapons specifically designed to cause permanent blindness to unenhanced vision.

Protocol V, which entered into force on 12 November 2006, recognizes the need for measures of a generic nature to minimize the risks and effects of explosive remnants of war.

Basic Principles on the Use of Force and Firearms by Law Enforcement Officials

Adopted at Havana by the Eighth United Nations Congress on the Prevention of Crime and the Treatment of Offenders, 27 August–7 September 1990

The document urges governments and law enforcement agencies to develop a range of means as broad as possible to equip law enforcement officials with various types of weapons and ammunition that would allow for a differentiated use of force and firearms. These should include the development of non-lethal incapacitating weapons for use in appropriate situations, with a view to increasingly restraining the application of means capable of causing death or injury to people. For the same purpose, it should also be possible for law enforcement officials to be equipped with self-defensive equipment such as shields, helmets, bullet-proof vests and bullet-proof means of transportation, in order to decrease the need to use weapons of any kind.

Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction (Chemical Weapons Convention, CWC)

Opened for signature at Paris on 13 January 1993; entered into force on 29 April 1997

The convention prohibits the use, development, production, acquisition, transfer and stockpiling of chemical weapons. Each party undertakes to destroy its chemical weapons and production facilities by 29 April 2012.

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Chemical and Biochemical Non-lethal Weapons: Political and Technical Aspects

Non-lethal weapons are intended to incapacitate personnel or materiel without injuring people. This Policy Paper describes and analyses biological and chemical substances that have the potential to be used as weapons or can improve the efficacy of other, more traditional, weapons. Potential loopholes in the international prohibitions against chemical and biological warfare are presented together with practical, politically feasible and technically useful policy options.

Chemical and biological substances may be used to incapacitate or influence human behaviour and can be used in both wars and other conflict situations, including for peacekeeping and some counterterrorism operations. The possible applications of science and technology for developing such agents are also expanding. This Policy Paper strikes the right balance between scientific detail and reader-friendliness to inform both the specialist and the generalist on this emergent and complex issue.

Dr Ronald G. Sutherland (Canada) is Professor Emeritus of Chemistry at the University of Saskatchewan. He has conducted research on organic and organometallic chemistry. His current focus is on chemical and biological weapons and environmental modification as a method of warfare. He is the author or co-author of more than 200 scientific publications. He also co-edited and contributed to *National Implementation of the Future Chemical Weapons Convention*, SIPRI Chemical & Biological Warfare Studies no. 11 (1990), and *Effective Implementation of the Chemical Weapons Convention: Proceedings* (1995) and co-authored 'Maintaining the effectiveness of the Chemical Weapons Convention', a SIPRI fact sheet (2002).

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