

## The duality of chemistry: Chemistry for peaceful purposes versus chemical weapons\*

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**Abstract:** In April 1997, the Chemical Weapons Convention (CWC) entered into force, banning chemical weapons (CW) worldwide and requiring their destruction under international verification by 2007, a date that has since been extended to 2012. At the same time, the CWC aims to prevent the recurrence of CW, including their possible use by non-State actors such as terrorists. The CWC is an agreement between governments, but it also sets norms that apply, through national laws and ethical principles, to the individual scientist and engineer. Many chemists, however, have had little or no exposure during their training and professional life to the ethical norms and regulatory requirements of the CWC. At the same time, advances in the life sciences are creating enormous opportunities—with the potential of being quite beneficial to humankind but also prone to abuse. Education and awareness-raising about the norms and principles enshrined in the CWC are therefore becoming increasingly important. Through its activities in the field of chemistry education as well as its links to the chemical industry, IUPAC has responsibility, as well as capacity, to promote professional conduct that is in full compliance with the norms of the CWC.

**Keywords:** chemical weapons; codes of conduct; dual use; Chemical Weapons Convention; chemistry education; governance.

### INTRODUCTION

On 29 April 1997, the Chemical Weapons Convention (CWC) [1] entered into force, banning the development, production, stockpiling, transfer, and use of chemical weapons (CW) worldwide. The CWC required the destruction of the declared stockpiles of CW under strict international verification by 2007, with a possibility of extending the destruction deadline to 2012. Six States have declared a total of 71 000 agent tonnes of CW. One (Albania) has already completed its destruction program. The other five (Russia, USA, India, Libya, and one undisclosed State Party) have made significant progress with the elimination of their CW stockpiles. They have, however, experienced delays in their destruction operations, and extensions have been granted. The two countries with the largest stockpiles (Russia and USA) have been granted extensions until 2012—the longest extension that is possible under the CWC.

In parallel, States that have joined the CWC are under the obligation to destroy or convert for peaceful purposes their former CW production facilities. This process is well underway. The 11 States Parties that have declared altogether 65 such facilities had destroyed, by 31 July 2007, 42 former CW production facilities. The number of converted CW production facilities stands at 19.

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In addition to its disarmament objectives, the CWC aims to establish a global multilateral non-proliferation regime. Its goal is to prevent the recurrence of CW, whether in the form of State programs or the use of toxic materials by non-State actors such as terrorists. To achieve this goal, the CWC establishes an international verification system. States Parties are to declare to the Organisation for the Prohibition of Chemical Weapons (OPCW) certain categories of industrial chemical facilities (as well as certain military facilities that manufacture small quantities of high-risk chemicals such as nerve or blister agents for defense purposes). The OPCW then conducts on-site inspections of these facilities to ensure that no CW are being manufactured there. In addition, the OPCW, following a request of any of its States members, has authority to conduct short-notice challenge inspections at declared and undeclared facilities and locations if there is doubt about a State Party's compliance.

As a safeguard against failure of this disarmament and nonproliferation regime, the CWC establishes an international mechanism to assist States Parties in case they are attacked or threatened with CW. It also facilitates the improvement of national capabilities for the protection against chemical attacks. Finally, it facilitates international exchanges in the peaceful uses of chemicals.

The CWC is an agreement among governments. But its norms also apply, through national laws and administrative measures, to natural and legal persons who come under the jurisdiction of the States Parties. Sustained efforts have been made by the OPCW over recent years to promote the adoption of effective national implementation measures by all of the 182 States that have joined the CWC. An action plan on the national implementation of the CWC has been carried out to this effect, and many countries have been assisted with the enactment of national implementing legislation and the development of effective enforcement measures.

## DUAL-USE NATURE OF TOXIC AND PRECURSOR CHEMICALS

At the foundation of the CWC is a definition of a CW that recognizes the dual-use nature of chemistry: rather than prohibiting specific chemicals that have been used in the past as chemical warfare agents, the definition of "chemical weapons" in the CWC covers all toxic chemicals (as well as their precursors) unless intended for legitimate purposes, as long as the types and quantities of these toxic chemicals or precursors are consistent with such legitimate purposes. This is usually referred to as the "general purpose criterion", because it builds the definition of a CW on the purpose for which a chemical was made or acquired.

This way of defining CW was necessary to ensure that despite the prohibitions of the CWC, toxic chemicals and precursor chemicals can continue to be used for peaceful purposes. Many of the chemicals that have a history as chemical warfare agents, or that are necessary for their synthesis, also have peaceful uses. Phosgene and chlorine, chemicals used as poison gases in World War I, are widely used in the chemical industry. Phosphorous trichloride and oxychloride are precursors in the production of the nerve agents, but also necessary as starting materials for the production of a range of phosphororganic chemicals, including pesticides, flame retardants, and many other products. Even the classical warfare agents can have certain peaceful applications (for example, sulfur mustard is used as a cancer treatment). And even if a warfare agent has no peaceful uses, there remain legitimate needs to have available small quantities either for research purposes, or for the development of new defensive equipment such as detectors, medical treatments, protective materials, or decontaminants.

But the general purpose criterion has a second effect: it keeps the definition of CW open for future discovery. A definition that is based on a closed list of prohibited chemicals would quickly become outdated. Basing the CW definition on intent ensures that any new chemical compound that may be discovered, either as the result of synthesis and screening or by extraction from natural sources, will fall under the concept of CW if someone would decide to use it as a CW agent. The prohibitions of the CWC cannot be circumvented by simply modifying the chemical structure of a known agent (in the same way as designer drugs are made), or by designing or discovering a new agent that was not put on

any control list. The definition of the CWC includes all known and unknown toxic chemicals and their precursors.

Such a concept, however, is not always easy to apply in the real world. The CWC therefore also contains three control lists (“Schedules”) of toxic and precursor chemicals. These Schedules trigger verification as well as national implementation measures (see Table 1). Above certain annual production thresholds, they trigger the declaration of chemical industry facilities that are to be reported annually to the OPCW and that may be subject to international on-site inspections by OPCW inspection teams. In addition to the Schedules, the CWC requires the declaration of chemical industry facilities that produce organic chemicals (with certain exceptions such as facilities that only produce high explosives or hydrocarbons). Particular emphasis is placed (for verification purposes) on organics that contain phosphorus, sulfur, or fluorine. Table 1 gives an overview of the Schedules and the different declaration and inspection thresholds as well as applicable export regulations.

**Table 1** Rules that apply to Scheduled chemicals as well as “discrete organic chemicals” (DOCs).

	Types of chemicals listed in the Schedule	Threshold for declaration to the OPCW	Threshold above which the facility is open for inspection	Export regulations
Schedule 1	High-risk agents and precursors with established history in chemical warfare, such as nerve and blister agents and certain key components of binary weapons	For protective purposes: 0 For research, medical, or pharmaceutical purposes: 100 g/a	For protective purposes: 0 For research, medical, or pharmaceutical purposes: 100 g/a	No export to States not party; each export to a State Party needs to be notified to the OPCW
Schedule 2	Medium-risk toxic and precursor chemicals with some civilian uses	BZ: 1 kg/a Other toxic chemicals: 100 kg/a Precursors: 1 t/a	BZ: 10 kg/a Other toxic chemicals: 1 t/a Precursors: 10 t/a	No export to States not party
Schedule 3	Toxic chemicals and precursors with large-scale and wide-spread civilian uses that pose a risk to the CWC	30 t/a	200 t/a	Exports to States not party require end-use certification
Plant sites producing DOCs	Not a Schedule; covered are all unscheduled DOCs	30 t/a	200 t/a	None under the CWC
Plant sites with one or more plant producing a DOC which contains P, S, or F (“PSF chemical”)	Not a Schedule; covered are all unscheduled DOCs that contain at least one atom of P, S, or F in their molecule	30 t/a	30 t/a	None under the CWC

At the level of national implementation, export controls and restrictions are to be applied by all States Parties to the scheduled chemicals to prevent their acquisition by proliferators. The transfer of Schedules 1 and 2 chemicals is restricted to States Parties; a country that has not joined the CWC can no longer import such chemicals from any State Party. As for Schedule 3 chemicals, exports to non-parties require the submission of an end-use certificate from a competent authority of the recipient country. In addition to these transfer restrictions of the CWC, some countries (the countries of the Australia Group, which includes all European Union countries, as well as other countries) also enforce export

controls with regard to certain other chemicals as well as certain types of equipment and technologies that are relevant to CW nonproliferation.

Since 2004, all States are under an obligation to enact and enforce measures to prevent access by non-State actors (such as terrorists or criminals) to dual-use chemicals, equipment, and technologies. This obligation was adopted under Chapter VII of the UN Charter, relating directly to threats to international peace and security. This legally binding Security Council resolution creates a world-wide regime that aims to curtail the proliferation of chemical (as well as nuclear and biological) weapons and related materials by and to individuals. This complements the prohibitions that apply under the CWC to the governments of the 182 States Parties. The global regime that bans CW is thus almost complete, and CW are clearly outlawed for all intents and purposes.

Does that mean that the issue of a possible misuse of toxic chemicals for hostile purposes has been resolved forever? If history offers any guidance, the answer should be "No". Not only are there a few remaining countries that have yet to join the regime (some of which certainly have the capability to produce CW; for a list of States not party to the CWC, see <<http://www.opcw.org>>), there also remain certain non-State actors that have shown an interest in developing and using chemical warfare capabilities in the past. The Tokyo sarin attack by the Aum Shinrikyo and the interest in CW shown more recently by Al Q'eda cannot be ignored. In addition, uncertainties remain about the way in which the CWC applies to toxic chemicals that some States have used, or intend to develop, for law enforcement purposes. "Law enforcement including domestic riot control" is one of the purposes which the CWC accepts as a legitimate purpose for the use of toxic chemicals. The recent use of a fentanyl-like compound in the Moscow theater siege has illustrated the potential utility of certain incapacitating chemicals as law enforcement agents, but it is only a step from that to the introduction of a weapon that disperses such a toxic chemical for warfare purposes. The interest currently shown by some governments in the development of such "nonlethal weapons" coincides with a period of rapid advances in the life sciences. It remains therefore important to critically analyze these developments and to ensure that any decision about the introduction of such weapons does not undermine the prohibitions of the CWC.

## THE IMPACT OF ADVANCES IN SCIENCE AND TECHNOLOGY

Advances in science and technology affect the CWC in a variety of ways: the discovery of new biologically active chemicals and of new carriers that can transport such chemicals to specific parts of the body, as well as the development of new dissemination methods using particle engineering and new aerosolization techniques, need to be reviewed in the light of the scope of the prohibitions of the CWC; technological advances may affect the way it is being implemented (including with regard to CW destruction and verification); and they may create opportunities for advancing international cooperation between States Parties in such areas as protection against CW and enhanced international cooperation in the peaceful application of chemistry.

To better understand the implications of these advances and to help with the preparations of the Second CWC Review Conference, which was held in April 2008, IUPAC and the OPCW organized an international workshop from 22 to 25 April 2007 in Zagreb, Croatia [2]. This was a second of its kind: already in 2002, IUPAC held such a workshop in Bergen, Norway, to prepare a report with findings and recommendations to the States Parties of the CWC and the OPCW, in preparation for the First CWC Review Conference [3].

The Zagreb workshop concluded that the life sciences are advancing at an unprecedented pace. Chemists, biologists, and engineers are among those who keep pushing the boundaries. The complexity of our knowledge of the molecular mechanisms of life's fundamental processes has dramatically increased in recent years. Chemistry and biology are ever more overlapping, making use of complementary advances in engineering and computer sciences. Drug discovery today starts with the selection of a disease and a related drug target. Large numbers of chemical compounds are being synthesized and screened in order to identify suitable lead compounds, making use of combinatorial synthesis methods

and automated high-throughput screening procedures. This involves the automated testing of large numbers of compounds against a large number of targets where, typically, several thousand compounds can be tested in 30–50 biochemical tests at the same time. Drug design is being facilitated as well as complemented by advances in molecular genetics and the mapping of the DNA of humans as well as microorganisms, and the use of computer-aided design of new lead compounds.

In addition, the understanding of the action of naturally occurring toxic chemicals (toxins) is also expanding. Current studies involve the isolation and characterization of such molecules from natural reservoirs, the development of modifications and derivatives of such chemicals, and studies to mimic their action—all the way to the synthesis and study of what may be called “artificial toxins”. As a consequence, the future toxin spectrum is likely to be more complex and more unpredictable than that of the presently known chemical and biological warfare agents.

The versatility of the chemical and pharmaceutical industry is increasing steadily. In addition to the marketing of new biologically active compounds as medicines or agrochemicals, new processes and technologies are being employed. More importantly, the manufacturing of chemicals is moving from traditional production locations in North America, Western Europe, and Japan to new locations in Asia, Europe, and South America. All this is creating enormous opportunities which can be tremendously beneficial for humankind. They can lead to significant improvements in public health, help increase food production, and more generally contribute to sustainable economic and technological development of countries across the globe.

But new scientific discovery can also be prone to abuse. The possibility cannot be ignored that in this life sciences revolution, new chemical compounds with potential CW utility may be encountered by chance, or developed by design. Whilst the deliberate development of a new CW agent requires a dedicated offensive CW program, attention should also be paid to the possibility of an inadvertent discovery of a new potential agent. Such inadvertent discoveries may happen when new chemical structures are synthesized and screened for biological activity. Usually, when developing new medicines or pesticides, chemicals that show unwanted toxicity are screened out and not further pursued. But that does not erase the information on their toxicity. That, and the large numbers involved in high-throughput synthesis and screening, make it highly likely that databases resulting from combinatorial research contain information on potentially highly toxic (or potent) structures that could be the starting point for the development of a new CW agent. The advances in the life sciences are making it ever more probable that such new structures will be discovered. There may in fact be some such structures already contained in combinatorial databases, and they could, at least in theory, be extracted with “database mining” techniques.

But the risk of new CW agents so emerging is moderated by the fact that time and effort required to develop a new potential agent into an effective weapons system remain considerable. To weaponize a new agent for military purposes, it needs to be purified to ensure long-term stability in storage. Tactical mixtures need to be developed to enhance the agent’s effects, stabilize it, or adjust the physical and chemical properties of the mixture to provide for effective dissemination or desired environmental behavior. Weapons testing needs to be done to ensure that the agent will be disseminated effectively, without excessive agent loss as a result of, for example, combustion (in case of dissemination by detonation) or ineffective dispersion (spray devices). Production technologies need to be developed to manufacture the large quantities of the agent needed in a military program. Protective means (detectors, protective material, medical counter-measures including antidotes, and treatment protocols) need to be developed. In short, from the perspective of a “traditional” State program for the development of CW, the emergence of new potential CW agents does not in itself change the status quo as long as there are no offensive military programs dedicated to exploiting such discoveries.

However, State as well as non-State proliferators may also opt for less effective CW. The case of Iraq has shown that under certain circumstances, CW do not have to be produced for long-term storage. Iraq never managed to purify the agents to the point where they were sufficiently stable for long-term storage. Instead, the production schedule was “synchronized” with weapons expenditure on the battle-

field. As far as non-State actors are concerned, the risk that they may take advantage of advances in science and technology and develop “high-tech” CW appears low. It is much more likely that such actors would attempt to use materials that are easily accessible to them. That could be achieved by manufacturing improvised chemical devices utilizing widely available materials, or by diverting (stealing) toxic industrial chemicals. There also is the risk that terrorists may attempt to release such materials from storage or transport vessels. To counter these threats, international as well as national nonproliferation and law-enforcement efforts—including measures to control access to relevant chemicals, equipment, and technology—are important safeguards. So are measures to increase preparedness to manage the consequences of releases of toxic materials, whether intentional or accidental.

With regard to new discoveries and scientific advances, chemicals are of particular concern that interfere with normal life processes and incapacitate the victim, but that have otherwise a relatively low lethal toxicity. Under the concept of “nonlethal weapons”, work is underway in several countries to develop chemical incapacitants that are supposed to have a sufficiently high therapeutic index so they can “safely” be used for law-enforcement purposes. The danger of these developments is that, contrary to the simple inadvertent discovery of a new potential agent, such programs combine the search for potent agents with the development of dissemination devices and other means that are needed to use them under field conditions. These are for all intents and purposes weapons, and a CW development program is no longer distinguishable from efforts to develop such “nonlethal” weapons for legitimate purposes. The protections that the CWC offers against the development of new CW may be undermined, and the demarcation between the legitimate uses of toxic chemicals (for law enforcement) and the prohibitions of the CWC may become blurred.

At the same time, it must be understood that a weapon that utilizes a chemical as its functional principle that interferes with human physiology or psychology cannot be characterized as “nonlethal”. A recent study by the British Medical Association concluded that it is “simply not feasible to use drugs as weapons without generating a significant mortality among the target population... The agent whereby people could be incapacitated without risk to death in a tactical situation does not exist and is unlikely to in the foreseeable future” [4]. A similar conclusion had been reached previously by the OPCW’s Scientific Advisory Board when it reported to the First CWC Review Conference that “based on past experience and the fact that many of these compounds act on the central nervous system, it appears unlikely from a scientific point of view that compounds with a sufficient safety ratio would be found” [5].

## GOVERNANCE IN THE FIELD OF SCIENCE AND TECHNOLOGY

The dual-use potential of chemistry has been reflected in the CWC’s general purpose criterion. Legally and conceptually, this is the most important safeguard against inadvertent discovery of new chemicals with CW potential, the development of novel agents, or the use of existing toxic chemicals for hostile purposes. When it comes to day-to-day implementation of, and compliance with, the requirements of the CWC, however, the general purpose criterion needs to be put into practice as a set of practical measures rather than an abstract concept.

This happens essentially at three levels: legislative, regulatory, and administrative measures taken by the State; voluntary (self-regulatory) measures adopted by the chemical industry and the scientific community; and the incorporation of CWC requirements into chemistry education.

### Legislation, regulations, and administrative measures

National implementation in the form of legislation, regulations, and administrative measures is at the heart of transforming international law into domestic law. The CWC regulates the behavior of States and governments. It establishes an international regime of prohibitions and requirements, and an international institution (the OPCW) to administer these requirements including by conducting verification

measures to ensure compliance by the States Parties with their undertakings under the CWC. In some legal systems (monistic), these prohibitions and requirements become automatically part of the laws of the land. In principle, they apply not only to the State but also to all its subjects. But even in such monistic legal systems, the CWC's prohibitions do not automatically link into the penal code and thereby to established penalties. Neither do they by themselves compel chemical companies to declare themselves so the verification measures foreseen under the CWC can be applied to them. The CWC's prohibitions and requirements need to be enforced in the given context, and to be able to do so some legislation is required in all States Parties no matter what their constitutional and legal structure.

The CWC recognizes this and explicitly requires States Parties to adopt the measures they need to implement the CWC, and in particular to incorporate the CWC's prohibitions into their penal legislation. It also requires States Parties to extend these prohibitions to their subjects (natural persons) abroad, and to enforce them in areas that come under their control (e.g., occupied territories or military bases abroad).

This national implementation of the CWC was for a long time a weak point of the regime. When the operations of the CWC were reviewed in 2003 by the First CWC Review Conference, it had become apparent that many States Parties had failed to enact the legislation they needed to enforce the Convention [6]. Many of those that had enacted legislation had done so in a less-than-comprehensive fashion. Many States Parties had even failed to take some of the most basic measures, such as to establish or designate from its existing agencies/ministries, a lead agency for the implementation of the CWC and point of contact for the OPCW and other States Parties (the "National Authority").

A practical consequence of this lack of implementation was that some States Parties lacked the tools to identify and declare to the OPCW their chemical industry facilities that were to be subject to verification including on-site inspection. That led to an unequal treatment of States Parties under what was supposed to be a truly nondiscriminatory regime. But with rising concerns about the possibility of terrorists using toxic materials as weapons, the concerns about this lack of implementation went well beyond the technicality of whether all industry facilities had in fact been declared. There was, and remains today, a concern that terrorists may exploit the fact that some States have not put legislation in place to criminalize activities related to the development, testing, and manufacturing of chemical (as well as biological, radiological, and nuclear) weapons and use the territory of such States as a "safe heaven" for their activities.

To rectify the situation, the OPCW decided in 2003 on an action plan to improve national implementation of the CWC and in particular to promote the establishment of fully authorized and competent National Authorities (including training of personnel) and the adoption of comprehensive implementing legislation by all States Parties. This 2-year action plan was followed by additional measures. Today, the vast majority of States Parties have a functioning National Authority. On the other hand, of the 182 States Parties, 69 still lack implementing legislation. In its most recent review, the OPCW noted the reasons for these delays: "The difficulties encountered by States Parties in taking steps to implement their Article VII obligations remain essentially the same as those reported in the past: a lack of awareness or an incomplete understanding of the complexities involved in national implementation, a lack of capacity in key areas such as legislative drafting and enforcement by customs authorities, a lack of resources, internal economic and political factors that create competing priorities, and other circumstances, including conflicts and war" [7].

Efforts of the OPCW and its Member States continue to provide assistance to States Parties with completing their national implementation measures and enforcing them. But to be effective, this must be complemented by an increase in awareness about the norms of the CWC in industry, the research community, and the wider scientific and technical community.

### **Voluntary measures taken by the chemical industry, codes of conduct**

The chemical industry has played an active role in the development and adoption of the CWC, the design of its verification system, and its practical implementation. This engagement dates back to the early 1980s, well before the CWC negotiations entered into their final stages. The industry had, of course, a strong interest in ensuring that the international verification system as well as the underlying national implementation systems would be technically sensible, not create unnecessary burdens for companies, not compromise confidential business information, and not pose any safety problems during inspections of chemical companies.

But the support of the chemical industry went further. A good number of chemical companies supported the initial phase of training of future OPCW inspectors and made chemical plants available for mock inspections. The industry also provided other training, for example, with regard to techniques and methodologies for the inspection of logistical information associated with chemical manufacturing.

After the entry into force of the CWC, the chemical industry remained a reliable and constructive partner in the implementation process. It received OPCW inspections, helped with the further refinement of the industry inspection scheme, and supported other OPCW programs, including in the area of fostering international cooperation in the peaceful uses of chemistry.

Going beyond simply complying with national regulations and laws, the industry has in the context of its Responsible Care<sup>®</sup> initiative developed voluntary measures that are to ensure that it does not contribute to the proliferation of CW. These measures include awareness-raising and training and the reflection of the nonproliferation requirements in the industry's codes of conduct. In 2003, the Council of Chemical Associations (ICCA), which represents chemical industry associations throughout the world, stated that its "support for the CWC is rooted in the chemical industry's voluntary Responsible Care<sup>®</sup> initiative. The CWC is one of many important tools industry employs to help fulfill its commitment to Responsible Care<sup>®</sup> in the management of chemicals worldwide... Implementation of Responsible Care<sup>®</sup> is consistent with the CWC's goals of fostering and furthering the peaceful use of chemistry and preventing the misuse of essential chemical products for making chemical weapons by developing and implementing effective safeguards on chemical products" [8].

The industry also clearly understood the link between implementing the CWC and helping prevent chemical terrorism. Marybeth Kelliher from the American Chemistry Council wrote in 2002: "The chemical industry is reassessing and enhancing its security in the wake of unprecedented terrorist attacks and in light of the continuing terrorist threat. This effort is well underway and draws upon the success of the CWC and proven industry programs, such as Responsible Care. While effective industry safeguards are already in place against diversion of chemicals for misuse, industry is establishing new partnerships and strengthening others in order to make continuous and informed improvements to its security for the future. The chemical industry approach continues to serve as a model for other industries and within government. Though no threats have been received specific to the chemical industry, the United States at large is at risk of attack. Industry realizes that these urgent circumstances call for nothing less than its best through increased prevention and preparedness, and constructive partnerships with law enforcement and security agencies. At the same time, industry has faith in and is fortunate to draw upon the credibility, reach, and promise of the CWC for advancing antiterrorism efforts worldwide" [9].

Whilst the industry has taken a lead in developing and applying voluntary codes which, amongst others, contain measures to ensure compliance with the CWC, the research and the wider scientific community has remained largely ignorant about the needs to address CWC compliance. Many chemists have had little or no exposure during their training and professional life to the ethical norms and regulatory requirements of the global CW ban. Some may know that such industrial chemicals as phosgene or chlorine once had a history as chemical warfare agents. Some may recall that there is but a small change in the molecular structure that distinguishes certain pesticides or flame retardants from nerve gas. And, of course, a moral taboo has been associated for centuries with the use of poison in



war. But how does that history affect the professional life of practicing chemists and chemical engineers today?

Education and awareness-raising about the norms and principles enshrined in the CWC are becoming increasingly important for the long-term stability of the regime that bans CW on a global scale. With the revolution in the life sciences well under way, it is important that researchers are aware of the norms. To discuss what can be done to improve the situation, IUPAC and the OPCW organized in 2005 an international workshop in Oxford, UK, that looked at requirements with regard to education, outreach, and codes of conduct to further the norms of the CWC. With regard to codes of conduct, the workshop concluded that a “code is required for all those engaged in science and technology using chemicals. The code needs to be widely crafted so as to be applicable to chemists, physicists, mathematicians, life scientists, etc. A code should not be restricted to scientists and engineers but should also be applicable to those making policy decisions, administrators, funding organizations and bodies, sales personnel, etc., and should apply throughout academia, industry, and government” [10].

Conceptually, one can think of such codes existing at several levels (layers): at a global scale, ethical norms and principles that are there to guide the behavior of scientists and engineers may be developed, and should include reference to the norms against CW. At the level of professional associations such as chemical societies or academies, the need for codes of conduct of their members should be addressed. And finally, it is useful to think in terms of the development and adoption of workplace codes, for example, at research institutes or teaching institutions.

Through its activities in the field of chemistry education as well as its links to the chemical industry, IUPAC has responsibility, as well as capacity, to promote professional conduct that is in full compliance with the norms of the CWC. International cooperation and exchanges in the fields of science and technology have great potential for improving public health, environmental protection, and sustainable development. At the same time, chemical research and international cooperation and exchanges should be pursued in recognition of the fact that they must be fully consistent with the disarmament and nonproliferation obligations of the CWC. In this context, the efforts made by the OPCW Scientific Advisory Board, together with IUPAC, to promote awareness of and compliance with the principles and norms of the CWC by the world scientific community should be taken up by national chemical societies and science academies in their own efforts to provide guidance to students and practicing chemists and engineers with regard to the ethical dimensions of their profession.

### Chemistry teaching

It will be important to bring these issues to students of chemistry, and to fold them into their professional education and training. In the same way in which the concern for human and environmental safety and knowledge about the applicable regulations and safety measures form today an organic part of the professional profile of every chemist and chemical engineer, respect for the norms of the CWC and an understanding of the relationship of one's own work to these norms must become a normal aspect of the professional ethics of chemists and chemical engineers.

To help chemistry educators who wish to incorporate CWC-related issues into their teaching, IUPAC undertook a project to develop an Internet-based educational module on multiple uses of chemicals and the CWC [11]. This module contains a series of short papers, case studies, and images that provide sufficient information for chemistry lecturers to prepare a lesson on the issue. At the same time, there is material for practical exercises, workshops, and seminars to deepen the understanding of the issues.

### CONCLUSIONS

The duality of chemistry—the enormous benefits it can bring to the common good but at the same time its potential for abuse or exploitation for hostile purposes—is reflected in the general purpose criterion

of the CWC: toxic chemicals (and their precursors) are all around us, and are used for a range of perfectly legitimate purposes. When they are developed, produced, or stockpiled with the intent of being used for hostile purposes (whether to poison an enemy in combat or innocent civilians in a criminal act or a terrorist attack), they turn into a CW. Chemical weapons are internationally banned; there is no legitimacy left that one could resort to for “justifying” their use.

New chemical compounds are synthesized every day; many of them are being tested for their properties as new medicines, pesticides, agrochemicals, and the like. It is inevitable that in this process, new compounds are discovered that might have utility as a CW. Equally important, chemicals are being manufactured and traded in large quantities and in many places across the globe. Some of these chemicals have utility as CW precursors or even as agents; some of them have in fact been used in the past as CW.

It is therefore important that those who work with chemicals understand this duality, are aware of the CWC and the related national laws and regulations, and understand their own responsibility for preserving and protecting the taboo against CW. IUPAC and national chemical societies and academies can play an important role in furthering this understanding and in promoting ethical conduct of the chemical profession worldwide.

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